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THE TECHNOLOGICAL MARKETPLACE

SUPPLY AND DEMAND FOR SCIENTISTS AND ENGINEERS

Third Edition

by

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SCIENTIFIC MANPOWER COMMISSION

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FOREWORD

This report reviews available studies of the past, present and projected supply of scientists and engineers, and their utilization in science and engineering.

Where there are differences of opinion about future supply and utilization, this study attempts to reconcile or explain those differences, or to supply an additional assessment. While neither this author nor others whose studies are incorporated here can be certain of future balance or imbalance between supply and demand, readers may find it helpful to have various projections available in the same document for their consideration.

In addition to endnotes and references to the text which start on page 48, the data sources utilized for figures and tables are listed beginning on page 50. The Bibliography on pages 53-54 is organized alphabetically by publisher.

Special thanks are extended to Tim Babco, Richard Vetter, and the staff of the Scientific Manpower Commission for their invaluable assistance.

Betty M. Vetter

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INTRODUCTION

Being able to assess whether supply and demand are or will be in fairly good balance over some period in the future is important to young people trying to plan their educations toward particular careers; to scientists and engineers already at work in the labor force who need to know where changes in balance are likely to occur; to colleges and universities and other training institutions; and to the employers of scientists and engineers. Although no perfect system for forecasting has been developed, available indicators provide useful information.

Who Needs Projections?

Young people thinking about career goals want to know whether there are likely to be employment opportunities in science and engineering fields, and, in general, what areas of science or engineering are most likely to need significant numbers of new entrants. While no one would advise students to choose a career solely on the basis of its apparent job opportunities at any particular time, this information helps them to make informed decisions when added to such other factors as personal aptitudes and interests, opportunities for education, and the number of years they are willing to spend in preparation before moving into the world of work.

Scientists and engineers who are looking for new opportunities, or whose fields are getting overcrowded may wish to examine peripheral fields, and start preparing themselves to make a shift at the most advantageous time. Those who do not look ahead may be totally unprepared to face a job shift if one becomes desirable or necessary.

Colleges and universities must plan ahead in developing faculty sizes, estimating student demand for particular courses and curriculums, and developing counseling programs. Such planning is assisted by information about the current and projected job market. Forecasts of over- or under-supply are among factors used by training institutions in deciding whether to add or drop particular programs.

Employers of scientists and engineers, including the colleges and universities that train them need information about potential shortages or surpluses of these professionals as a part of their long range planning. If a shortage of engineers appears to be developing, for example, an individual employer might wish to take steps to encourage those already in his employ to stay there; to see that opportunities for an engineering education are offered to young people in his community who might not otherwise be able to undertake such education; or to institute programs to upgrade current technical employees.

Although the kinds of information needed by each of these individuals or groups may be different in its level of sophistication, knowledge of the general trends is important for each of them.

How Projections Are Made

Assessing the future is difficult in any area, and particularly difficult when trying to anticipate how well the demand for people with particular kinds of training will match with the number of people trained over a period that must be at least four years and often eight or ten years ahead. There are a number of unknown factors in the equation needed to make such projections, and some assumption must be made for each of these unknowns.

Developing a model to predict whether supply and demand will be in balance at some period in the future requires making assumptions about what young people entering college may decide to study, and the basis on which that decision will be made; the level of funding that will be available from any and all sources to employ the scientists and engineers who will be seeking jobs; and how each of these will affect the other. At present, there are no perfect predictive models, or even any that consistently have worked well in the past.

Several kinds of models are used. One forecasting method projects what has happened in the past into the future. There are any number of variables that can be used within this kind of trend projection model, including heavier weighting of the most recent time period involved in the projection, or weighting for other factors such as an expected increase in the participation of women in areas where they have not previously been engaged in large enough numbers to be significant. The simplest trend models of supply use basic demographic information such as the number of young people who will reach age 18 or 22 in any year ahead; and assume that the behavior of this group will be similar to the behavior of earlier cohorts in terms of the proportion that will choose to enter science and engineering. Such models then estimate the supply of new entrants over some particular period of time in the future, and add this number to the present supply. Using available demographic data from the past, such a model will then subtract appropriate numbers for each year for death and retirement, emigration, and transfers to other fields. Additions will be made for immigrant scientists and engineers and for transfers from other disciplines. The result will be an estimate of the number of persons who should be available and trained at any particular point in the future.

This trend model can be adjusted by weighting any factor more heavily or by adding into the model a predicted effect for such changes as tuition increases, drops in federal funds for student grants and loans, increases in student populations by the introduction of older students, or changes in student choices occasioned by differences in entering salary levels or student perceptions of employment opportunities. Both the simple and the more complex trend models show a mixed record in predicting future supply. Trend models may give poor results if one or more factors reverse direction or even slow or speed the rate of change. For example, projections of degrees made ten, and even four years ago, failed to anticipate the rapidity of increase in the participation of women in science and engineering.

One way of projecting demand for the near future is to ask a number of knowledgeable persons from major employing companies or institutions about their hiring plans; to combine and average or weight their responses and compile a statistical forecast. For example, a large number of industrial employers may be asked about their plans for hiring more scientists and engineers over certain periods of time in the future. Such respondents generally are asked to separate anticipated hiring to indicate how many will be hired as replacements for persons expected to leave and how many are expected to be net increases in the total number employed. The responses are then aggregated, producing an estimate of the number of scientists and engineers who are likely to be hired by all such employers if plans do not change. Of course, plans do change, and if the plans of a number of participants change in the same direction, the estimates will fail substantially to meet the reality.

Projections of demand sometimes are made by estimating a value for some factor such as the Gross National Product, and assuming that some proportion of the GNP can be translated into jobs for scientists and engineers. Research and Development budgets, correlated with cost per scientist or engineer, can be used to estimate demand for some activities.

Still other projections are based on an effort to predict how much funding will be applied to solve a particular problem such as protecting the environment, developing new weapons systems, or working toward energy independence. This kind of projection is not particularly useful in determining total manpower demand for scientists and engineers unless many other problem sectors also are projected at the same time and with the same set of basic assumptions. Therefore, such projections often are made under several different scenarios - which assume increased or reduced emphasis on one or more national endeavors.

Some projections recognize the fact that if jobs are not available in the area of training, individuals will seek employment elsewhere, either within or outside the S/E workforce. When demand increases, some, but not all, of these individuals will return to employment within their original fields.

How Projections Are Used

In every case, projections for the future require that some assumptions be made about both present and future factors that will affect the supply of or the demand for scientists and engineers. The projections themselves may affect the outcome. For example, when high demand is projected for a particular area, more students will enroll in programs that will prepare them for those jobs.

Right or wrong, such assessments, if widely publicized, can change supply, and therefore the balance between supply and demand, by influencing the actions of potential students, employers, and training institutions. Some of these influences are inadvertent, and some are intentional.

Projections may result in modification of the amount of support available to assist students to obtain training in science and engineering, in order to increase or decrease the available manpower a few years later. Through most of the 1960s, since most projections indicated a shortage of trained people in almost all fields of science and engineering, support for the training of scientists or engineers was increased. After 1968, however, support declined, particularly for graduate students, and doctorate production in these fields leveled off and then dropped. For example, the proportions of full-time graduate students in doctorate-granting institutions who were supported by fellowships or traineeships fell from its Fall 1968 peak of 33% to 15% in Fall 1982. The proportion supported by research assistantships stayed between 19% and 23% over those years. As the amount of student support went up in the 1960s the number of S/E Ph.D.s also increased - from 6,263 in 1960 to 16,059 in 1969. Through the seventies, however, despite an increasing population base, the number of S/E Ph.D. awards dropped off.

Even though the art of forecasting presently is inexact, and indeed sometimes grossly in error, forecasts are one of the necessary tools for planning. Such forecasts should be monitored and updated on a regular basis.

A DECADE OF SUPPLY AND DEMAND

Beginning during World War II, and continuing through the 1960s, rapid technological advancements and an increasing population resulted in the utilization of almost all the scientists and engineers available, and the economy displayed a voracious appetite for more. There were chronic shortages of certain kinds of scientists and engineers through the middle fifties, and great efforts were made to increase the number of persons trained in those areas, both for traditional activities and for such special programs as space exploration. By the middle sixties, these efforts in the form of scholarships and fellowships and G.I. educational benefits, coupled with a rapid increase in the number of college-age students and in the proportion of this group entering higher education, resulted in a substantial increase in the number of science and engineering graduates.

Because these programs had been set in motion with the assumption that shortages would continue indefinitely, no long range plans were developed to assess continued need for them. Thus, in 1967, when budgets for the space program hit their peak, young men (and an occasional woman) were still pouring into the educational pipeline to prepare for careers in aerospace engineering, and indeed in all fields of engineering. Even by 1969, when budget figures for space and other programs were dropping steadily, freshmen engineering enrollments were still holding steady. It was not till 1971 that the big drop occurred (18%). First year enrollments continued to drop for two more years before the perceived job market turned them up again.

Unemployment For Scientists And Engineers

In addition to dropping budgets in the space program, the economy began to falter following years of inflationary guns-and-butter budgets. Industry as well as government not only reduced hiring substantially but also began large layoffs of engineers and scientists. By 1971, the unemployment rate for engineers and some scientists reached 3% (fig. 1) even as record classes of new graduates at all degree levels poured out of colleges and universities to swell their ranks.

Following a drop in unemployment in 1973, the unemployment rates started up again in 1974 and peaked in 1975 for engineers and probably in 1976 for scientists.[1] Although the unemployment rates for engineers had been somewhat higher than for scientists in 1971, engineers showed lower unemployment rates than scientists through the remainder of the decade. Both in 1972 and in 1976, the unemployment rate for scientists exceeded the rate for all professional and technical workers. High national unemployment rates in the early 1980s were not reflected in science and engineering until 1982, when these rates also began to climb.

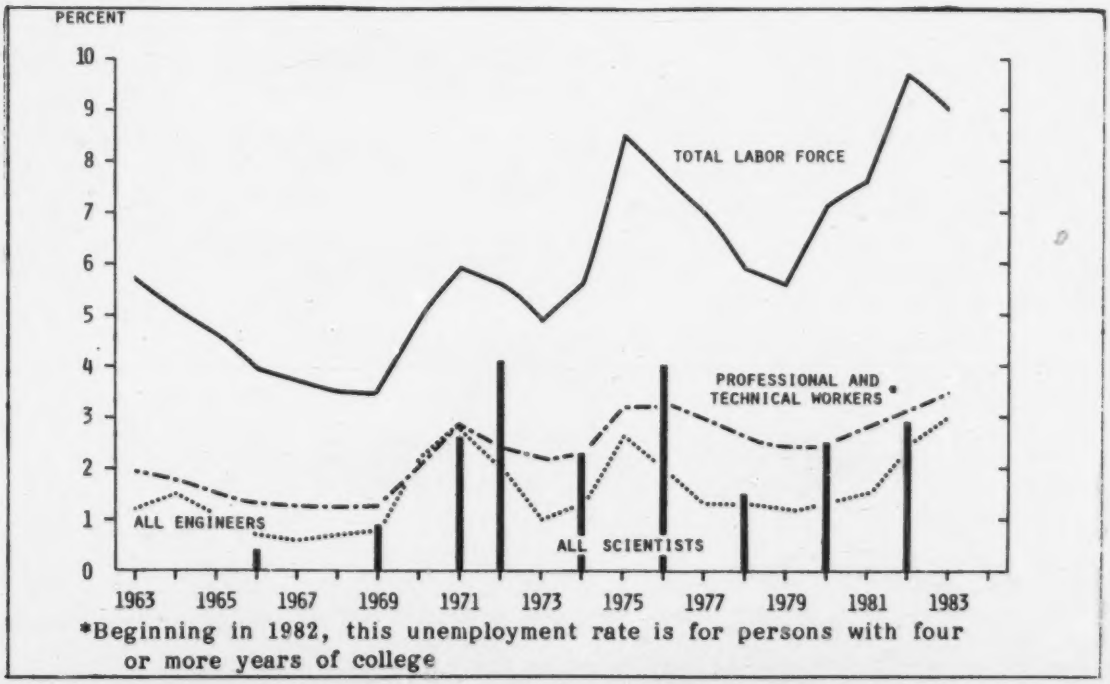

Figure 1. Unemployment Rates [Data Sources: Bureau of Labor Statistics, National Science Foundation, National Research Council]

Over the decade of the seventies, both scientists and engineers became increasingly aware of the seriousness of oversupply problems, and the degree awards in most of the science fields have dropped consistently since 1972.[2] On the other hand, freshmen engineering enrollments bottomed out in 1973, and rose steadily through 1982 in response to a good job market for graduates. However, responding to a reduction in offers in 1982 and 1983, as well as reflecting the drop in the number of 18 year olds in the population, freshmen enrollments dropped in Fall 1983 for the first time since 1973.[3]

The variation in supply/demand imbalances in the various fields of science and engineering indicate the need to examine these fields separately, and in as much fine field detail as available data allow.

Doctoral Scientists And Engineers

Unemployment rates among doctoral scientists and engineers have been measured in alternate years since 1973.[4] The total unemployment rate hovered near 1% through most of the decade, rising slightly to 1.2% in 1973 and 1977 (fig. 2).

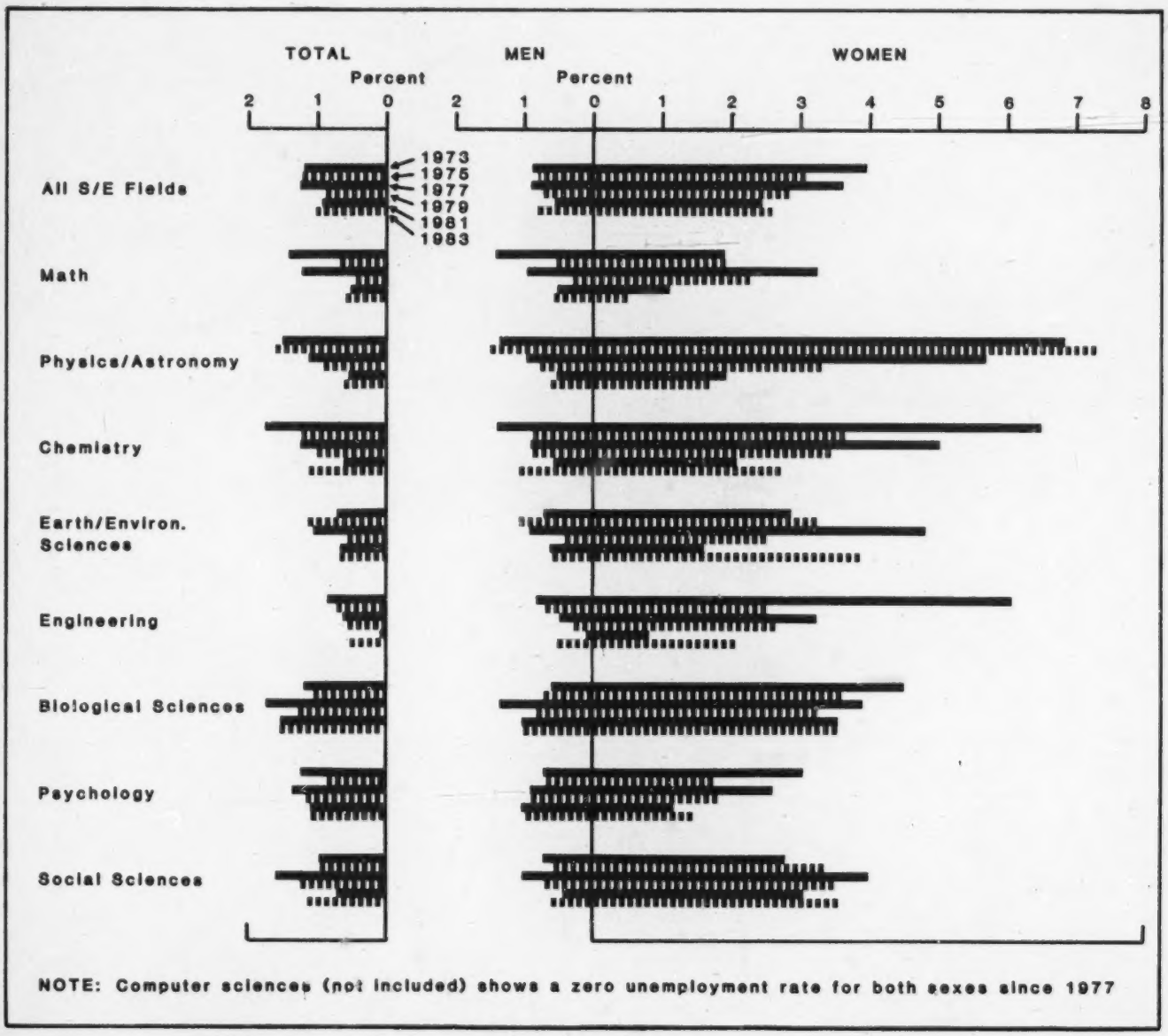

Figure 2. Unemployment Rates of Doctoral Scientists and Engineers
[Data Source: National Research Council]

By field, physics and chemistry had the highest unemployment rates in 1973 and 1975, but the biological and social sciences had the highest rates after 1977. The lowest unemployment rates have been in computer science, where no cases of unemployment have been reported since 1977, and in engineering.

Unemployment rates for women have remained consistently three to four times higher than for men in every survey year. In part, this may reflect the higher proportion of younger graduates in the female doctoral population, since unemployment has been somewhat higher for more recent graduates than for those who have been in the labor force longer.

Recent Science And Engineering Graduates

One indicator of imbalance between supply and demand can be seen in the rate of science or engineering employment and of unemployment among recent bachelor's and master's graduates in these fields. While an educational background in science and engineering is excellent preparation for a wide variety of occupational endeavors, either an exceptionally high unemployment rate amoung recent graduates in these fields or an unusually low science and engineering utulization rate generally indicates an oversupply.

Unemployment rates among bachelor's and master's graduates one and two years after receipt of the degree, measured since 1972,[5] indicate that the highest unemployment rates

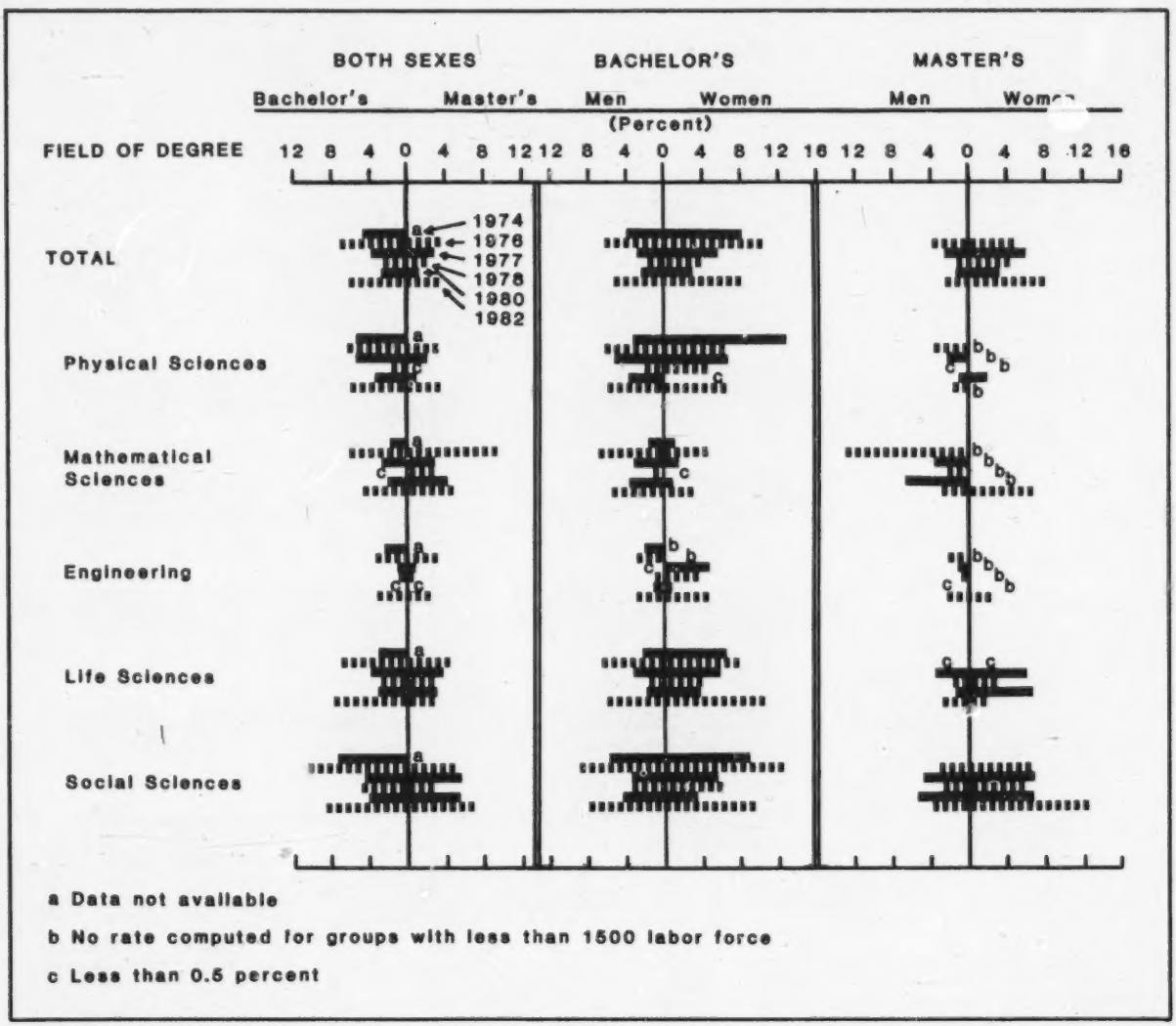

Figure 3. Unemployment Rates of Science and Engineering Bachelor's and Master's Graduates Two Years After Graduation, 1974, 1976, 1977, 1978, 1980 and 1982
[Data Source: National Science Foundation]

occurred in 1976 when the 1974 graduates were surveyed. Almost 8% of the bachelor's graduates and 4% of the master's graduates were unemployed and seeking work two years after earning the degree (fig. 3). After dropping for the next three surveys, the rates rose again in 1982 when the 1980 and 1981 graduates were surveyed. The unemployment rates were highest among graduates in the life and social sciences, but all fields show the increased rate for the 1982 survey class. National unemployment peaked in 1982, and the rates probably have dropped for graduates of 1983 and 1984.

Almost without exception, the unemployment rates for women have been higher than for the men with whom they graduated, and this has been true through each succeeding survey, although the gap in the unemployment rates between recent men and women graduates continues to decrease in some fields. This apparent preference of employers for male graduates also can be seen by examining the proportion of the employed graduates in each field who found science and engineering employment (fig. 4).

Bachelor-level computer scientists and engineers of both sexes are the most likely of all the science and engineering graduates at this level to be employed in science and engineering jobs; and social and behavioral graduates the least likely to find S/E employment. While this might indicate an undersupply of engineering graduates and an oversupply of graduates in the social and behavioral sciences, it is more related to the typical entry level for

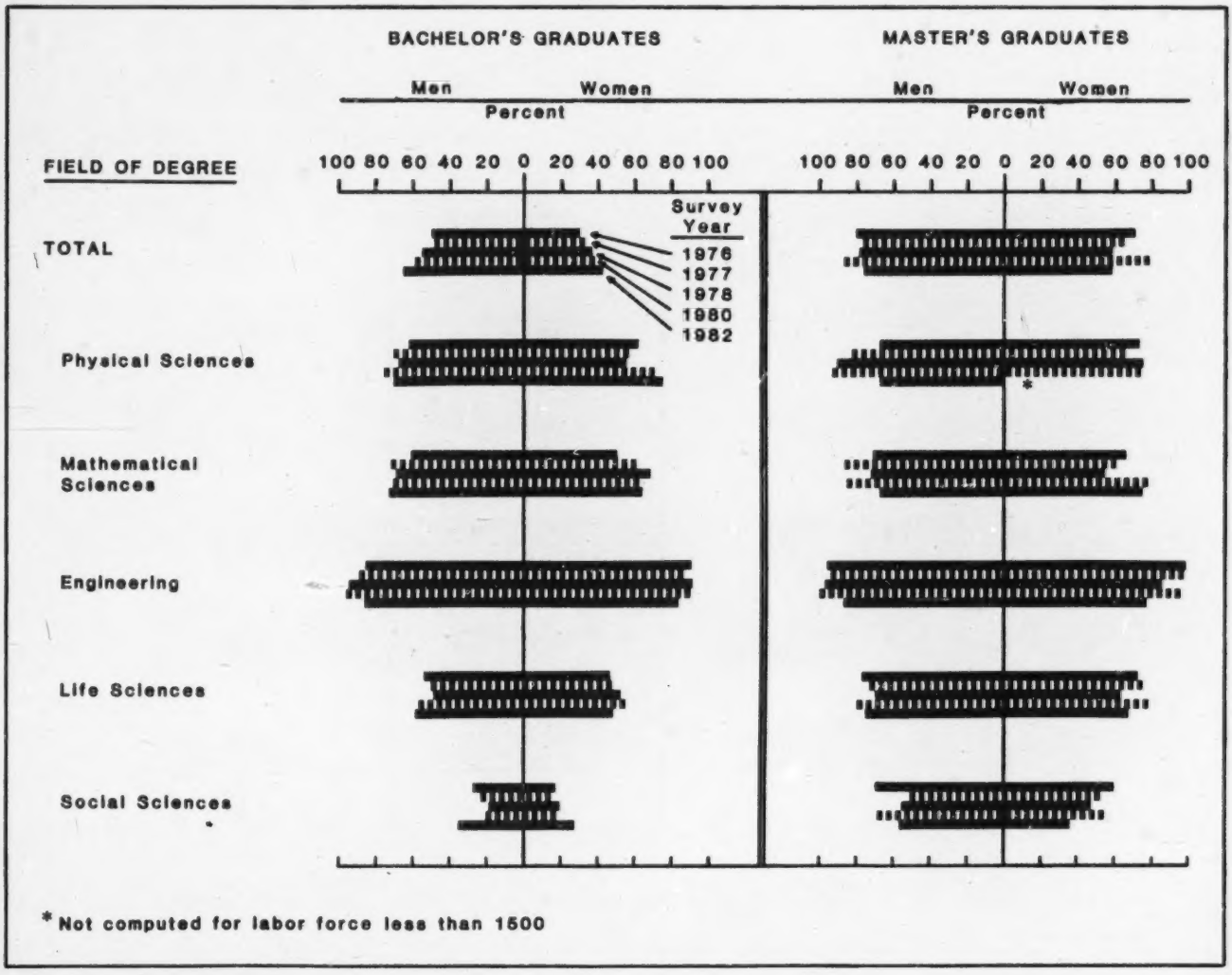

Figure 4. Percent of Employed Science and Engineering Graduates Working in S/E Jobs One to Two Years After Graduation, by Field and Level of Degree and Sex
[Data Source: National Science Foundation]

these fields. A bachelor's degree is sufficient for professional employment in engineering or computer science, but a graduate degree is generally required for professional entry to the social or life sciences.

About half of the male and 30% of the female bachelor's graduates in science and engineering of the class of 1974 who were employed in 1976 were employed in science or engineering jobs. By 1982, when the 1980 and 1981 classes were surveyed, 65% of the men and 42% of the women who were working were in S/E jobs, despite higher unemployment rates for

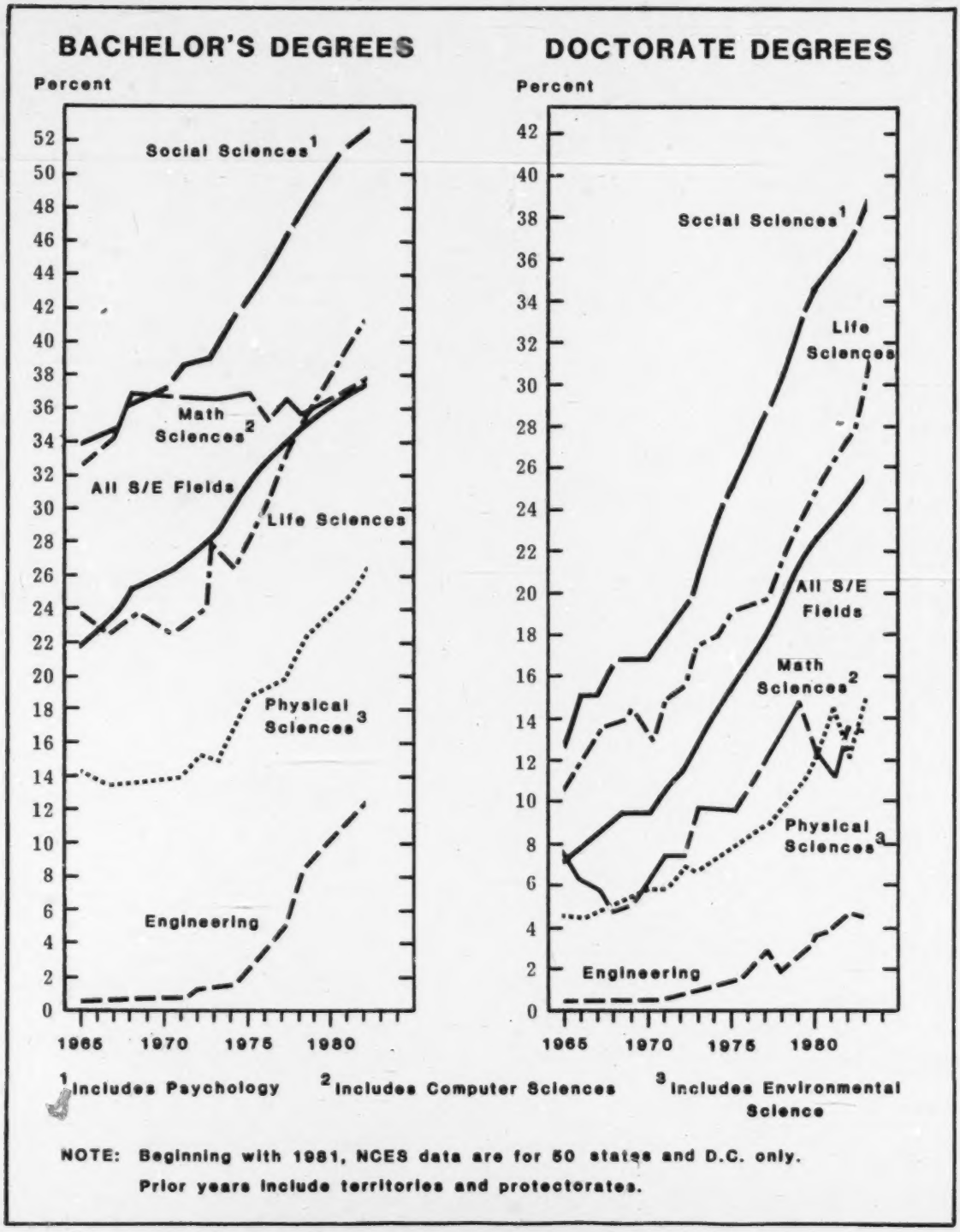

Figure 5. Percent of Degrees Earned by Women [Data Source: National Center for Education Statistics, and National Research Council]

both sexes. Much of the difference between men and women can be attributed to their field of degree, but not all of it.

Among master's graduates, the proportion employed in science or engineering is higher for both sexes, (76% for men and 59% for women in 1982), but the difference between men and women persists across all major fields except math and computer sciences.[5]

SUPPLY

The science and engineering pool is made up of persons already trained and in the labor force with new additions and subtractions constantly occurring. Persons are lost from this pool by death, retirement, and transfer out of these professions. Persons are added in four ways: by the input of new graduates at all degree levels; the immigration of previously trained scientists and engineers from other countries; the transfer from other related disciplines; and by "upgrading." This latter process usually results from on-the-job experience, but sometimes it happens when qualified entrants cannot be recruited. Thus, the "upgraded" entrant, particularly in engineering where non-degreed engineers are a major component of the engineering work force in some data, may be qualified only within narrow limits.

New Graduates

Two significant changes occurred in the seventies in the supply of new graduates: a drop in total S/E degree awards and a change in the sex ratio of students earning science and engineering degrees. The total number of

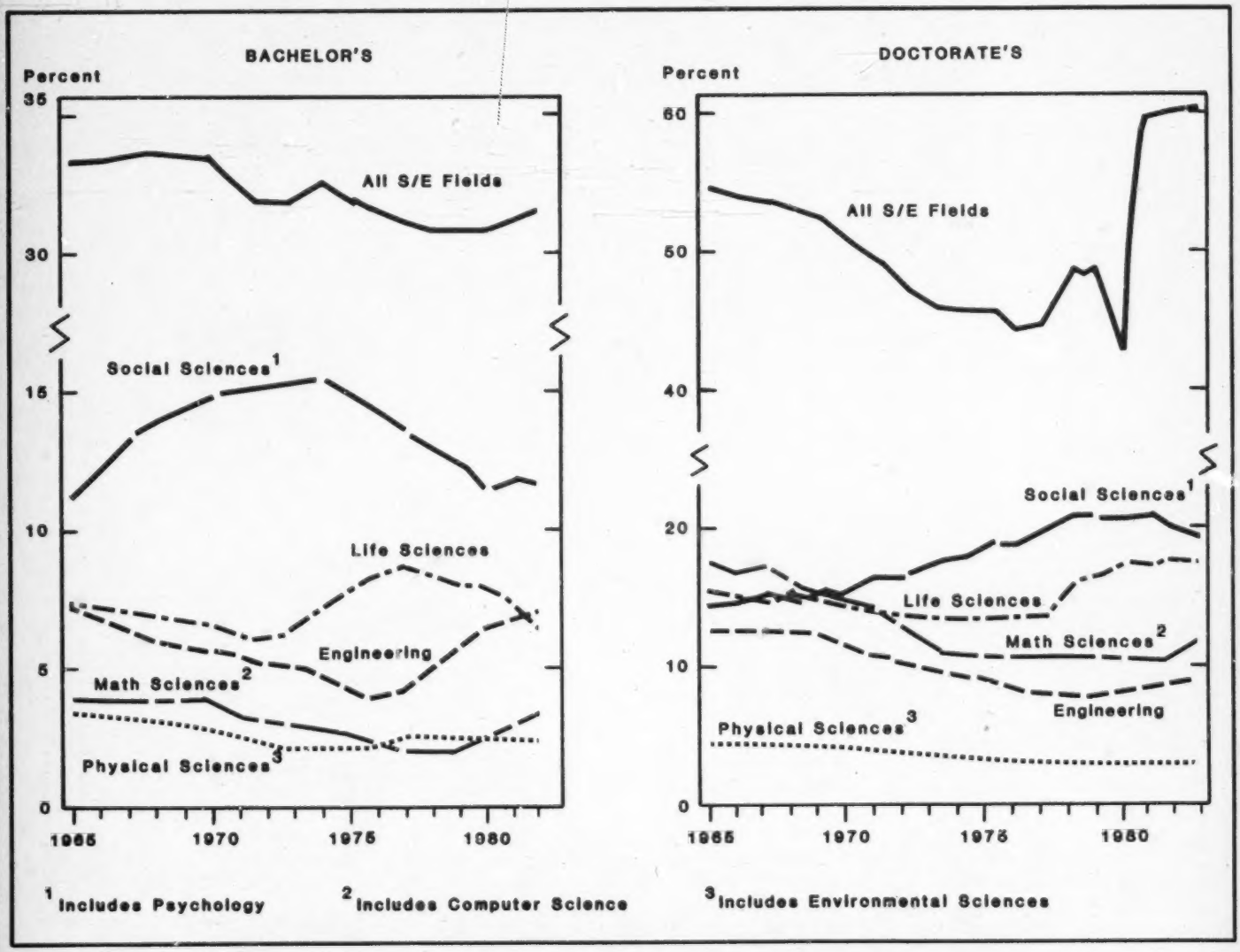

Figure 6. Science and Engineering Degrees as a Percent of All Degrees Awarded, 1965-1983
[Data Source: National Center for Education Statistics]

science and engineering bachelor's degrees awarded in 1982 was only 6.1% greater than the number in 1972, but the number awarded to women rose 44% while the number awarded to men dropped 8.2%. Women earned 28% of the science and engineering bachelor's degrees awarded in 1972, and 37% of those awarded in 1982 (fig. 5).[2]

At the doctoral level, the change is even more dramatic. In 1983, the total number of science and engineering doctorates awarded was 1% less than the number awarded in 1973, but the number earned by women was up 98% while the number awarded to men dropped 15%. Women earned 13% of all science and engineering doctorates in 1973 and 26% in 1983. These increases in the number and proportion of women earning degrees occurred across all fields and at all degree levels (fig. 5).[6]

The second change in science and engineering degrees that occurred during the seventies is that the total number of degrees awarded in these fields dropped as a percentage of all degrees awarded, particularly at the doctoral level. In 1960, degrees in science and engineering were 62% of all doctorates awarded. By 1979, they were only 50%. These proportional changes by broad field are shown in figure 6. The proportion of S/E degrees started up again in the eighties.

A remarkably consistent 29% to 32% of bachelor's graduates have majored in science or engineering over the past three decades, with internal field changes swinging the emphasis to and from the social sciences, life sciences and the EMP (engineering, math and physical science) fields. In 1960, 16.7% of all bachelor's degrees were in EMP fields, dropping to 8.3% in 1976, before starting up again to reach 12.8% in 1982. There is a continued increase in engineering, and a proportional drop in the social sciences after 1974.[2]

However, the drop in S/E doctoral degrees since 1966 may be even more significant than it appears if we consider the increasing number and proportion of these degrees awarded to foreign nationals on temporary visas. In 1966, in ten science and engineering fields where 88% of the S/E doctorates were awarded, 15.3% were awarded to foreign citizens on temporary visas. By 1983, those same fields accounted for 73% of all science and engineering doctorates, and 22.4% of the S/E degrees were awarded to students on temporary visas (Table 1).[6] The shift is greatest in engineering, where the proportion of doctorate awards to foreign citizens on temporary visas increased from 16.7% of the total in 1966 to 42% in 1983. Other fields showing unusually high proportions of foreign recipients include agriculture, mathematics, economics and physics.

TABLE 1

PERCENT OF S/E DOCTORAL RECIPIENTS WHO WERE FOREIGN NATIONALS ON TEMPORARY VISAS, SELECTED YEARS

FIELD	1962 %	1966 %	1970 %	1974 %	1980 %	1983 %
Physics/Astronomy	13.7	12.2	11.3	17.2	19.2	24.6
Chemistry	9.7	11.1	7.9	10.2	15.4	16.1
Earth/Env. Sci.	9.2	12.9	13.9	16.1	12.7	16.6
Mathematics	16.8	12.6	10.9	18.5	18.7	29.8
Economics	17.2	20.1	17.2	22.0	25.0	25.9
Political Sci.	19.1	13.0	9.3	10.8	11.9	13.9
Engineering	17.9	16.7	13.7	22.4	34.3	42.1
Biological Sci.	14.4	14.3	10.5	10.5	7.8	8.6
Medical Sci.	14.6	18.6	16.6	9.4	11.3	13.7
Agricultural Sci.	23.8	30.4	25.3	33.2	32.6	31.2
TOTAL - 10 Fields	15.2	15.3	12.5	16.7	18.8	22.4
TOTAL - All Fields	10.8	10.6	8.7	10.2	11.7	14.4

Data Source: National Research Council

In the 1980s, probably the most significant change that will affect the number of new bachelor's graduates is the decrease in the size of the college age population. To some unknown extent, this drop may be compensated by an increase in the proportion of high school graduates of either sex who complete a college degree; by a continuing increase in the number of re-entry students, principally women, from earlier college-age cohorts; or (depending on the popularity of S/E majors among students) an increasing proportion of those degrees being awarded in S/E fields.

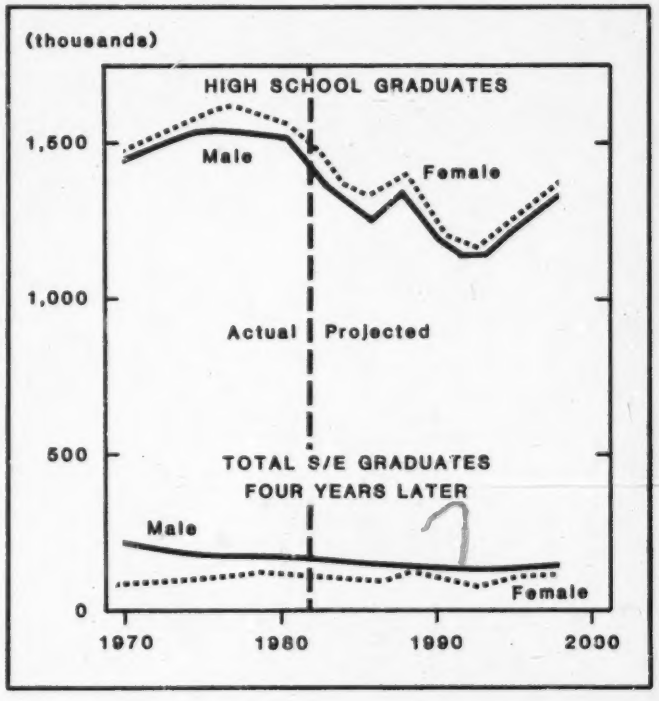

Figure 7. High School Graduates and S/E Bachelor's Graduates Four Years Later, 1970-1982
[Data Sources: Bureau of Census, NCES and Scientific Manpower Commission

The projections shown in figure 7 assume that 71% of males and 76% of females from the average of the 17 and 18 year old population will graduate from high school through 1998. To project the potential number of S/E bachelor's graduates, the assumption is made that the number of male bachelor's degrees in science and engineering will be 12.5% of male high school graduates four years earlier. This ratio increased from its low of 11.8% for the high school class of 1975 to 12.2% for the class of 1979,[7,8] and is assumed to rise to 12.5% by 1986 and hold at that ratio through the next 15 years. For women, the 6.5% ratio for the high school class of 1975 rose to 7.0% for the class of 1979 and is assumed to continue to increase by one-tenth of one percent each year to a total of 8.3% for the high school classes of 1991 through 1998.

If the job market in science and engineering, relative to the market in other degree fields as perceived by high school graduates, remains good or gets better, the proportionate increases could be somewhat higher for both sexes. The percentage of male high school graduates of 1970 represented by S/E bachelor's degrees awarded to men four years later was 14.9%. On the other hand, if high school seniors perceive the job market in science or engineering to be poor relative to other degree fields or to opportunities for non-college graduates, the number of S/E degree awards could be substantially below the numbers projected in figure 7.

Over a short range of years, the number of new graduates should be the least difficult segment of supply to project, although both the extent and the rate of change in the sex ratio of degrees awarded has been underestimated by every national set of projections over the past decade.

In engineering, we can begin to count the number of degrees expected by examining enrollments in engineering at the freshmen year. In the sciences, where a graduate degree is more likely to represent the professional entrance level, some data are available on enrollments in the junior year. However, advanced degrees are more typically projected by utilizing the ratio of baccalaureate degrees to first year graduate enrollments, and relating this in turn to degree awards a few years later.

During the seventies, although increasing numbers of students entered and graduated from the nation's institutions of higher education, including its graduate schools, the number of bachelor's degrees awarded in science and engineering peaked in 1974 and the number of doctorates in 1973 (figures 8 and 9). Spurred by the rapid increase in engineering

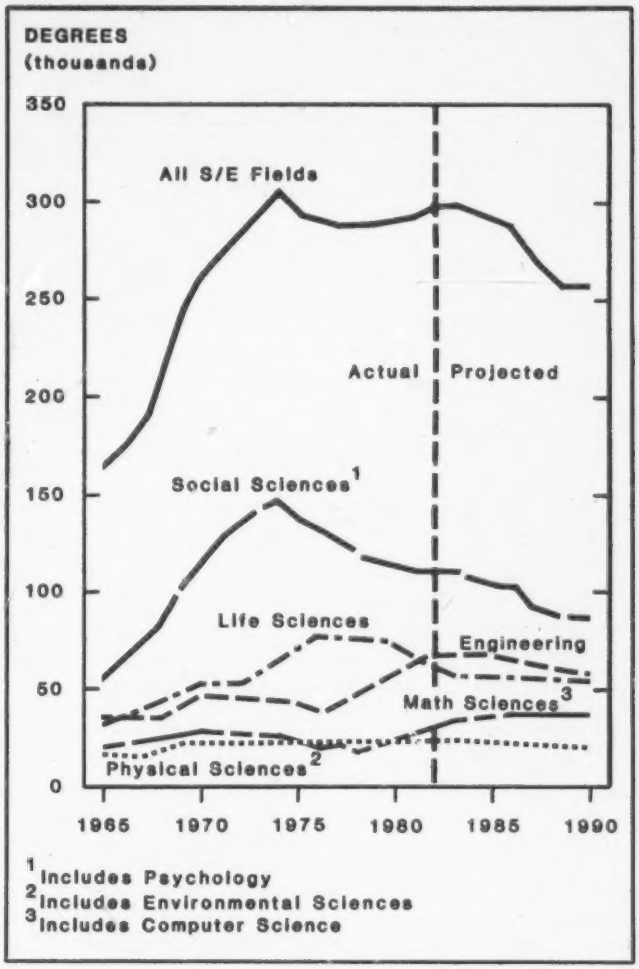

Figure 8. Science and Engineering Bachelor's Degrees, 1965-1982, Projected to 1990
[Data Source: National Center for Education Statistics and Scientific Manpower Commission]

degrees since 1977, the total number of science and engineering bachelor's degrees started up again in 1979 and rose through 1982. At the doctoral level, S/E degree awards started up again in 1978. This latest increase is made up of women (who increased their proportion of S/E doctorates from 13% in 1973 to 26% in 1983) and of foreign citizens, who earned 24% of S/E doctorates in 1983 compared with 21% ten years earlier.

Over the next decade, the number of bachelor's degrees awarded in science and engineering can be expected to drop fairly steadily through 1998 because of the decrease in the 18-24 year old age population group. The number of women earning these degrees is not expected to drop as fast as the number of men, because an increasing proportion of women graduates will earn their bachelor's degrees in some field of science or engineering. The

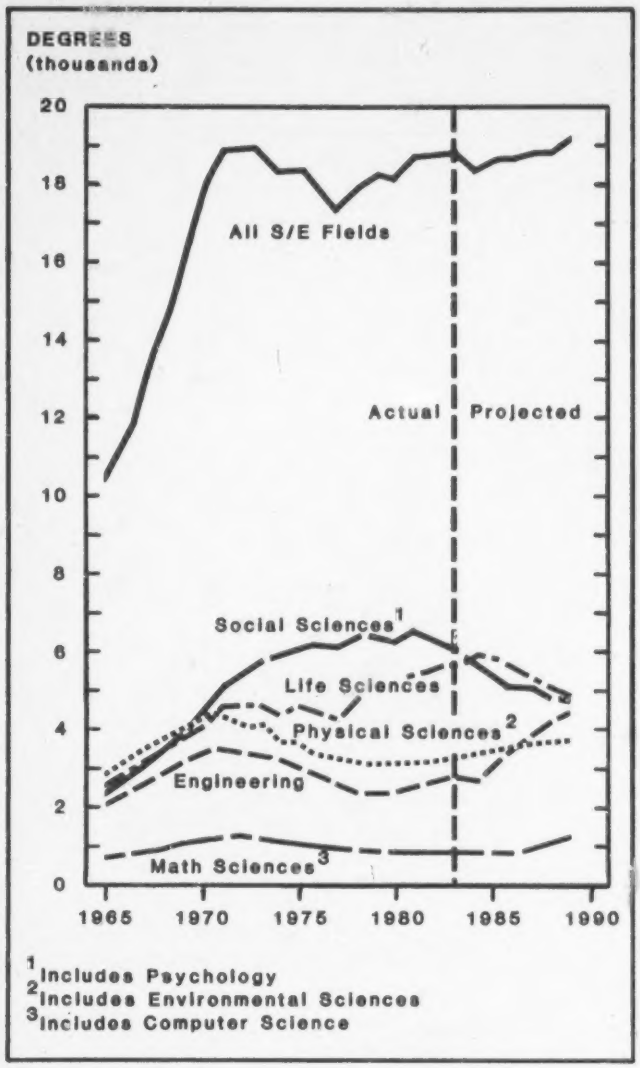

Figure 9. Science and Engineering Doctoral Degrees Awarded, 1965-1983, Projected to 1989 [Data Sources: National Research Council, National Center for Education Statistics and Scientific Manpower Commission]

projections shown in figure 8 are based on an assumption that about 12 percent of male high school graduates will earn bachelor's degrees in some science or engineering field; and that the proportion of women high school graduates who earn these degrees will rise slowly from seven percent of the high school graduates of 1978 to 8.3 percent of those graduating in 1991.

Within fields, some shifts will occur. These shifts are expected to result from student perceptions of opportunities in the various fields of science and engineering, which will raise the proportion of the total S/E graduates now majoring in math and computer science from 10.7 percent in 1982 to about 14 percent by 1987. The physical sciences are assumed to continue to make up about eight percent of all the S/E degrees at the bachelor's level and engineering about 23 percent. Life science degrees have dropped from 26.8% of all S/E bachelor's degrees in 1978 to 21.4% in 1982, and will probably average about 21 percent through the decade. The social/behavioral sciences group, which peaked at 47.7% of all S/E degrees in 1974, has dropped steadily since that time, and is estimated to level off in 1987 at about 34% of the total.

Projections of doctorates are based on graduate degree attainment rates from bachelor's to doctorate over seven year intervals, by sex and broad field. The total number of S/E doctorates is expected to stay approximately level from 1984 through 1989, but the number of men earning these degrees declines each year except in engineering and the math/computer science groups, while the number of women increases in all fields.

Because the supply of new graduates is not changing consistently within every field of science or engineering, it is helpful to look separately at several of these fields.

Engineering

In engineering, where we can get a measure of intended majors even at the freshman year, the enrollment drop from the fall of 1970 to the fall of 1973 was 29%. Freshman enrollments leveled off in 1973 and started up again the following year to rise for a decade. In part, this increase is made up of women who were 4.9% of the entering class in 1973 and 17% of the fall 1983 freshmen. The number of men also increased, in response to excellent job propects for graduates and high starting salaries. Overall, the freshman class rose 122% from fall 1973 to fall 1982. For the first time in a decade, the fall 1983 class size dropped from the previous year (4.9%).[3]

When freshman enrollment is plotted against first degrees four years later (fig. 10), we see not only the abrupt shifts in popularity of engineering among freshmen, but also a major change in the ratio of baccalaureate degrees to freshman enrollments four and a half years earlier.

The freshman class is reduced by attrition, especially after the freshman year, and augmented by input from two-year colleges (particularly at the junior level) and transfers from other subject areas. The continuing higher ratio of degrees to freshman enrollment appears to have leveled off at around 70%, as the size of the junior class relative to the

previous year's sophmore class has continued to increase. If this pattern continues, the graduating class in 1986 should peak at about 81,000 and the 1987 class should drop to 76,400, with women constituting 16.5% of the graduates (Table 2). The SMC projections of engineering degrees in Table 3 for the years 1988 to 1998 are based on the projected number of high school graduates four years earlier, and estimated at 4.6% of male and 0.9% of female graduates - proportions which match well with actual degrees awarded in earlier years and with some, but not all projections derived by different methods.

For example, two models are used by Robert Dauffenbach and Jack Fiorito[9] to project both near term and intermediate term engineering degrees, by field of engineering. In the near term, the authors conclude that baccalaureate degree production will continue its upward trend, at a relaxed pace, in the immediate future, with an increase of 6,000 or 7,000 degrees over the 1983-87 period, as compared with an actual increase of about 13,500 over the 1980-83 period.

The increase would not be evenly distributed across engineering fields. Civil and industrial degrees would rise less than others. For advanced degrees, the basic trend of this

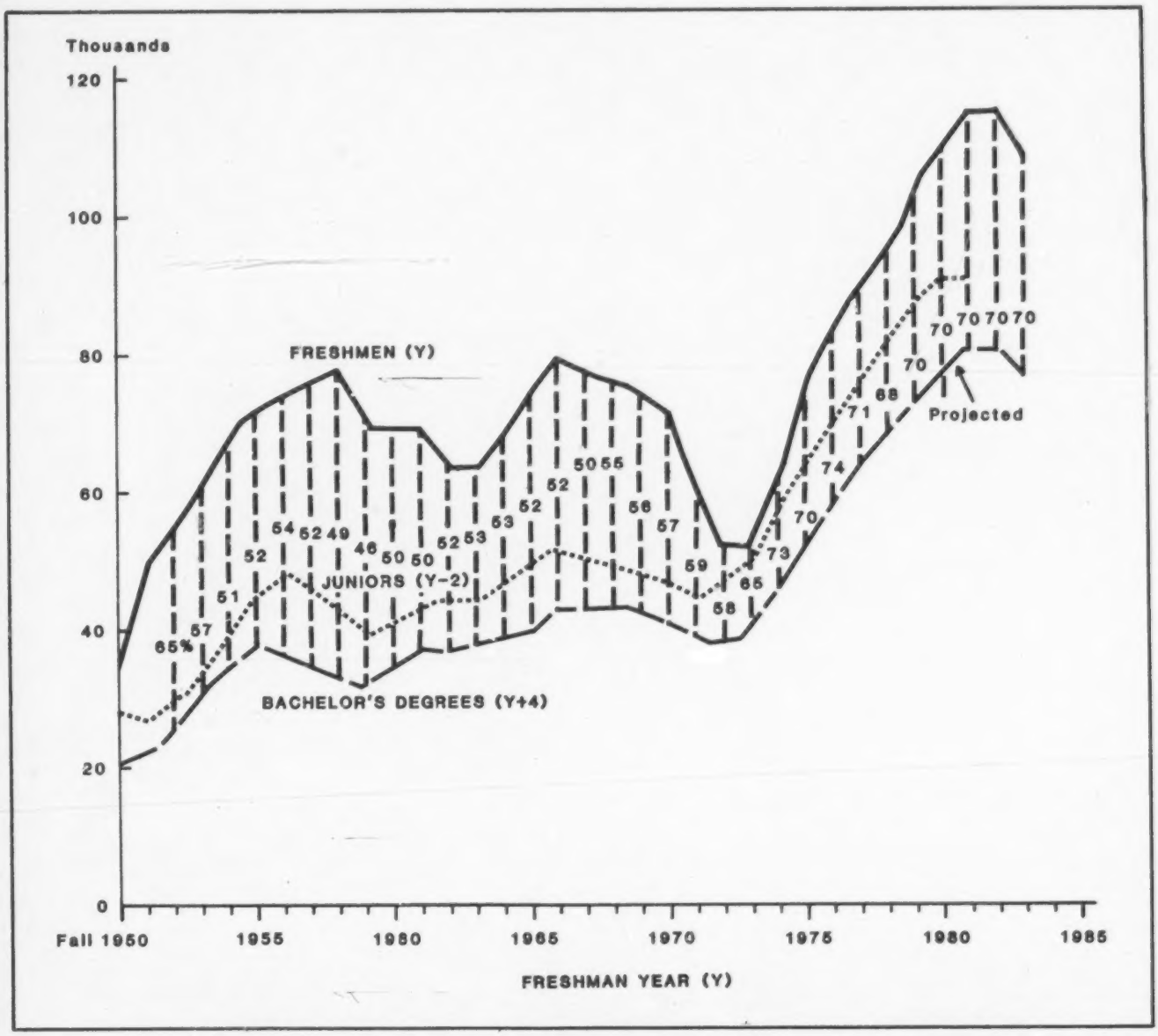

Figure 10. Freshman Enrollments, Junior Enrollments and B.S. Graduates in Engineering from Each Succeeding Freshman Class, and Ratio of Graduates to Freshmen Four Years Earlier
[Data Source: Engineering Manpower Commission with Projections by author]

TABLE 2

BACHELOR'S DEGREES IN ENGINEERING AS A RATIO OF FRESHMAN ENROLLMENT FOUR YEARS EARLIER

Freshman Class Year Fall	Bachelor's Degree Year	MEN			WOMEN		
		Freshmen	B.S. Degrees	Ratio	Freshmen	B.S. Degrees	Ratio
1969	1973	72,932	42,805	58.7	1,181	624	52.8
1970	1974	70,204	40,663	57.9	1,457	744	51.1
1971	1975	57,025	37,332	65.5	1,541	878	57.0
1972	1976	50,558	36,594	72.4	1,542	1,376	89.2
1973	1977	49,512	38,134	77.0	2,417	1,961	81.1
1974	1978	59,178	42,815	72.4	4,266	3,280	76.9
1975	1979	68,613	47,873	69.8	6,730	4,716	70.1
1976	1980	73,705	53,062	72.0	8,545	5,680	66.5
1977	1981	78,859	56,390	71.5	9,921	6,557	66.1
1978	1982	87,016	58,850	67.6	11,789	8,140	69.0
1979	1983	89,693	62,705	69.9	14,031	9,535	68.0
1980	1984	94,145	66,238	70.3	16,004	10,693	66.8
1981	1985	97,042	68,123°	70.2°	18,238	12,294°	67.4°
1982	1986	97,065	68,140°	70.2°	19,155	12,910°	67.4°
1983	1987	90,949	63,846°	70.2°	18,689	12,596°	67.4°

*Average of most recent 4 years
°Computed from ratio

DATA SOURCE: Engineering Manpower Commission - Estimates by Author

near term model is positive, with master's degrees rising to about 22,000 by 1989 and Ph.D.s increasing to about 4,000 by 1987. Chemical, electrical and mechanical engineering will account for the bulk of the increase at the master's level, with a large relative increase projected for mining and petroleum engineers in the short term projections. A 33 percent increase by 1987 in Ph.D.s over the 1983 level will be more evenly distributed across fields, with even civil engineering showing a healthy increase.

This model also attempts to delineate short term degree projections for women, minorities and foreign nationals in engineering. As shown in Table 4, the number of bachelor's degree awards is expected to rise through 1987, with the number awarded to women increasing from 9,566 in 1983 to 12,720 in 1987. The model's projection for 1984 was for 10,571 degrees, and the actual number awarded to women was 10,761.

Projections for Asian and foreign students also rise through each of the four years, while those for blacks, Hispanics and American

TABLE 3

ENGINEERING BACHELOR'S DEGREES, BY SEX, 1969-1984 AND PROJECTED TO 1998

YEAR	TOTAL	MEN	WOMEN
1969	39,972	39,644	328
1970	42,966	42,608	358
1971	43,167	42,814	353
1972	44,190	43,665	525
1973	43,429	42,805	624
1974	41,407	40,663	744
1975	38,210	37,332	878
1976	37,970	36,594	1,376
1977	40,095	38,134	1,961
1978	46,095	42,815	3,280
1979	52,598	47,873	4,716
1980	58,742	53,062	5,680
1981	62,935	56,390	6,545
1982	66,990	58,850	8,140
1983	72,240	62,705	9,535
1984	76,931	66,238	10,693
Projected by SMC			
1985*	80,417	68,123	12,294
1986*	81,050	68,140	12,910
1987*	76,442	63,846	12,596
1988**	72,660	60,350	12,310
1989**	70,880	58,880	12,000
1990**	70,490	58,560	11,930
1991**	71,820	59,660	12,160
1992**	73,600	61,180	12,420
1993**	71,320	59,290	12,030
1994**	66,350	55,150	11,200
1995**	63,860	53,100	10,760
1996**	60,640	51,700	8,940
1997**	61,475	52,400	9,075
1998**	61,215	52,200	9,015

* Based on enrollments at Freshman Year

** Based on number of high school graduates four years earlier - 4.6% for men, 0.9% for women

SOURCE: Engineering Manpower Commission
Scientific Manpower Commission and
National Center for Education
Statistics

TABLE 4

BACHELOR'S AND DOCTORAL DEGREES IN ENGINEERING PROJECTED TO 1987 (1983 Actual)

	Women	Blacks	Hispanics	Am. Ind.	Asian	For. Nat'l	Total
Bachelor's							
1983	9,566	1,862	1,883	97	3,098	6,151	72,471
1984	10,571	1,998	2,112	103	3,567	5,918	76,672
1985	11,529	2,059	2,189	108	4,146	5,919	77,177
1986	12,325	2,023	2,172	100	4,527	6,020	78,018
1987	12,720	1,935	2,138	94	4,447	6,234	79,731
Ph.Ds.							
1983	143	19	41	0	173	1,192	3,023
1984	152	13	44	1	150	1,469	3,248
1985	187	17	55	2	186	1,685	3,443
1986	221	17	50	1	180	1,656	3,619
1987	269	25	56	1	259	1,884	4,003

SOURCE: Deuffenbach and Fiorito.

Indians drop in 1987. The projections for bachelor's degrees in 1984 were lower than actual degrees for blacks and Asian Americans, and higher than actual degrees for Hispanics, American Indians and foreign nationals.

At the doctoral level, degree awards are assumed to rise from 3,023 to 4,003, increasing each year to 1987. The 1984 projection was for 3,248, and the actual number awarded was 3,234. The number awarded to women was assumed to rise from 142 in 1983 to 169 in 1987, and the estimate for 1984 (152) was almost exactly on the mark with the actual number (153). Estimates were too low for 1984 for

TABLE 5

INTERMEDIATE-TERM DEGREE PROJECTIONS TO 1995 WITH 1981 ACTUAL DEGREES

Year	Aero/ Astro	Chem	Civil	Elec	Ind	Mech	Mining/ Petrol	Other	Total
				Baccalaureate Degrees					
1981	1,587	6,863	10,795	14,558	3,460	13,462	2,085	10,125	62,935
1982	1,763	7,058	10,892	16,162	3,629	15,144	2,448	10,225	6,721
1983	2,019	7,194	10,888	16,906	4,252	15,979	2,494	10,890	70,624
1984	2,162	7,549	11,078	18,457	4,611	17,097	2,762	11,183	74,898
1985	2,238	7,601	10,850	19,273	4,597	17,554	3,090	11,844	77,046
1986	2,241	7,287	10,942	20,001	4,453	17,563	3,481	12,321	78,290
1987	2,297	7,238	11,286	21,004	4,562	18,128	3,520	12,743	80,778
1988	2,359	7,233	11,643	22,067	4,716	18,739	3,562	13,166	83,485
1989	2,436	7,293	12,064	23,285	4,913	19,463	3,623	13,647	86,724
1990	2,522	7,396	12,520	24,609	5,131	20,260	3,691	14,153	90,283
1991	2,626	7,562	13,055	26,127	5,383	21,201	3,778	14,734	94,466
1992	2,742	7,768	13,638	27,787	5,655	22,239	3,874	15,355	99,059
1993	2,865	8,002	14,252	29,557	5,936	23,344	3,974	15,995	103,925
1994	2,967	8,178	14,754	31,133	6,165	24,270	4,037	16,489	107,993
1995	3,087	8,412	15,342	32,936	6,428	25,358	4,119	17,066	112,747
				Master's Degrees					
1981	309	1,326	3,529	3,845	2,045	2,495	312	3,972	17,914
1982	425	1,440	3,503	3,996	2,022	2,569	344	4,279	18,579
1983	445	1,408	3,524	4,138	2,064	2,614	361	4,347	18,902
1984	467	1,442	3,584	4,307	2,111	2,686	371	4,412	19,378
1985	490	1,454	3,646	4,454	2,175	2,747	375	4,498	18,940
1986	510	1,483	3,719	4,615	2,228	2,815	383	4,574	20,326
1987	529	1,504	3,784	4,762	2,268	2,876	390	4,662	20,774
1988	546	1,524	3,860	4,907	2,303	2,934	397	4,745	21,215
1989	564	1,547	3,945	5,059	2,348	3,001	402	4,827	21,694
1990	581	1,573	4,033	5,214	2,396	3,071	406	4,911	22,187
1991	599	1,601	4,125	5,374	2,447	3,145	411	4,997	22,700
1992	617	1,631	4,220	5,538	2,499	3,221	416	5,085	23,228
1993	635	1,663	4,319	5,709	2,553	3,301	421	5,176	23,777
1994	653	1,696	4,420	5,884	2,608	3,385	426	5,269	24,342
1995	671	1,731	4,524	6,065	2,665	3,470	431	5,364	24,922
				Doctorate Degrees					
1981	114	312	406	503	157	339	58	952	2,841
1982	124	334	429	551	192	368	59	1,005	3,062
1983	125	361	404	610	167	396	49	1,105	3,219
1984	133	364	401	630	175	403	52	1,112	3,269
1985	138	366	402	646	178	412	52	1,119	3,313
1986	143	369	405	665	183	521	54	1,122	3,362
1987	148	372	407	679	188	428	54	1,136	3,412
1988	152	377	412	697	192	436	55	1,146	3,466
1989	154	379	414	710	194	441	56	1,162	3,510
1990	156	380	418	722	195	445	57	1,176	3,549
1991	158	382	423	736	197	451	58	1,189	3,595
1992	161	385	429	750	199	458	58	1,202	3,642
1993	163	388	435	765	202	464	59	1,217	3,693
1994	166	392	441	780	205	472	59	1,231	3,746
1995	168	397	448	796	208	479	59	1,247	3,802

SOURCE: Dauffenbach and Florito

blacks and Asians, and too high for the other groups.

These short term projections are based on enrollment data. The model used to project the intermediate term to 1995 utilizes the demographic variable of the number of 18 year olds and the demand variable of the 1995 level of occupational employment forecast by the Bureau of Labor Statistics to project both enrollments and subsequent degrees. This model projects a steady increase in bachelor's degrees to a level of about 113,000 by 1995 if the BLS employment projections are to be realized. The authors note that they expect this projection to be viewed "with a marked degree of incredulity"[9] by readers. However, if the economy continues on a steady growth path, they believe the intermediate term projections may prove nearer the mark than those derived solely from current enrollments. The intermediate projections are shown in Table 5.

The intermediate term master's projections remain comparatively stagnant as did the short term projections, while doctoral degrees are projected to rise in the intermediate term extrapolations in a manner that is inconsistent with the short term extrapolations. From a level of 2,841 Ph.D.s in 1981, doctorate production is projected to rise by about 1,000 by 1995. In the short term projections, an increase of 1,000 was expected by 1987 over the level of 3,000 achieved in 1983. However, much of that increase comes from foreign nationals.

Both the more conservative SMC projections and those by Dauffenbach and Fiorito assume that demand for engineering graduates will continue at a level where almost all of the graduates who wish to enter engineering employment will find such employment, and that beginning salaries for engineering graduates will stay high relative to salaries offered to baccalaureate graduates in other fields. If this does not occur, even the more conservative SMC estimates may be too high.

SMC assumes that total undergraduate enrollment in engineering probably peaked in 1984-85 and the number of graduates will peak in 1987. The Dauffenbach/Fiorito model would demand continuing enrollment increases at both undergraduate and graduate levels through at least 1993.

If 1985 or subsequent classes continue to find difficulty in obtaining employment, as happened for 1983 and 1984 graduates, both freshman enrollments and transfer applications probably will drop after 1985.

Added to the engineering graduates at the baccalaureate level will be graduates in engineering and industrial technology. Such four-year graduates now number about 12,000 per year,[7] and are expected to remain between 10,000 and 12,000 through 1989[8] (Table 6). Women also are increasing their proportion in this population - from 1.3% in 1973 to 6.7% in 1982 and can be expected to hold or increase this representation at least over the next four years. They made up 2.8% of freshmen enrollments in bachelor of technolgy programs in 1973 and 9.9% in 1980. Their share of total full-time undergraduate enrollment has climbed from 2.3% in 1973 to 8.4% in 1980.[3]

TABLE 6

BACHELOR'S DEGREES IN ENGINEERING AND INDUSTRIAL TECHNOLOGY

YEAR	TOTAL	WOMEN
1973	6,478	70
1974	6,443	40
1975	7,909	85
1976	7,079	48
1977	7,682	193
1978	9,366	311
1979	8,714	366
1980	10,048	537
1981	11,657	718
1982	12,984	875

SOURCE: Engineering Manpower Commission

Because demand for engineering bachelor's graduates did not quite keep pace with the increasing size of the graduating classes over the first half of the eighties, some needed increase occurred in graduate enrollments and degrees. Typically, following a year when more baccalaureate graduates than usual are unable to find immediate employment, freshmen enrollments drop and first-year graduate enrollments rise, as in 1972.[3] When employment prospects at the bachelor's level are excellent, freshman enrollment rises and graduate enrollment in engineering drops, as in 1976. As engineering employment opportunities increased through the second half of the seventies, the number of U.S. students going on to complete a Ph.D. has continued to drop, but the less favorable job market of 1982 and 1983 encouraged an increase in graduate enrollment.

The number of doctoral degrees in engineering fell through most of the seventies, despite increasing enrollments of foreign students. Foreign students on temporary visas now earn more than one-fourth of the master's degrees and 39% of the doctoral degrees awarded by U.S. universities[7] (Table 7). These figures do not include foreign citizens who are U.S. immigrants. Even among doctoral graduates who are not on temporary visas, many are not U.S. citizens. The National Research

TABLE 7

GRADUATE DEGREES IN ENGINEERING

YEAR	MASTER'S Total	MASTER'S Foreign Nationals	MASTER'S % Foreign Nationals	Ph.D.'S Total	Ph.D.'S Foreign Nationals	Ph.D.'S % Foreign Nationals
1969	14,980	1,784	11.9	3,387	410	12.1
1971	16,383	2,952	18.0	3,640	741	20.4
1972	17,356	2,973	17.1	3,774	773	20.5
1973	17,152	2,551	14.9	3,587	708	19.7
1974	15,885	3,099	19.5	3,362	1,014	30.2
1975	15,773	3,250	20.6	3,039	891	29.3
1976	16,506	3,691	22.4	2,977	1,060	35.6
1977	16,551	3,825	23.1	2,814	995	35.4
1978	16,182	3,720	23.0	2,573	874	34.0
1979	15,624	3,944	25.2	2,815	929	33.0
1980	17,243	4,512	26.2	2,751	982	35.7
1981	17,914	4,589	25.6	2,841	1,054	37.1
1982	18,543	5,284	28.5	2,887	1,167	40.4
1983	19,909	5,145	25.8	3,023	1,192	39.4
1984	21,226	5,731	27.0	3,234	1,277	39.5

SOURCE: Engineering Manpower Commission

Council's 1983 report on doctorate recipients found that among engineering Ph.D.s of that year, 53.5% are foreign citizens, although only 42% were on temporary visas (Table 1).[6] Thus, even among those graduates who will remain in the U.S. after completing the doctorate, many may be less fluent in English than is desirable for teaching undergraduate engineering students.

Physics

In physics, undergraduate enrollment peaked in 1969 and dropped steadily through the seventies. Beginning in 1980, enrollment of physics majors in the junior year started up again, and in 1983-84, that number again reached the 1972-73 level (Table 8). This drop in enrollment reduced demand for physics faculty, and a significant fraction of new physics Ph.D.s found placement difficult over the decade.[10] The number of Ph.D. awards dropped steadily through the seventies, and has stabilized in the early eighties. The smaller graduating classes found better employment opportunities, particularly because the foreign students and graduates continued to increase while the number of U.S. citizens in this population declined. By 1983, Ph.D. graduates included 27% foreign citizens.[6]

While the number of women entering physics has been increasing, they have not yet affected total supply significantly. Women earned 13% of the bachelor's, 12% of the master's and 7% of the doctoral degrees in 1982.[2]

Geosciences

In the geosciences, where demand increased with the search for new energy sources in the mid and late seventies, bachelor's and master's degrees have risen steadily since 1971 (Table 9). Much of the increase is made up of women. The number of male bachelor's graduates rose 74% from 1971 to 1982, while the number of women increased 382%, for a total increase of 108.9%.[2]

TABLE 9

GEOSCIENCE DEGREES

Year	BACHELOR'S Total	BACHELOR'S Women	BACHELOR'S % W	MASTER'S Total	MASTER'S Women	MASTER'S % W	Ph.D's Total	Ph.D's Women	Ph.D's % W
1971	3,330	379	11.4	1,084	113	10.4	550	15	2.7
1972	3,861	489	12.7	1,299	150	11.5	580	21	3.6
1973	4,273	544	12.7	1,416	183	12.9	577	22	3.8
1974	4,834	800	16.5	1,604	201	12.5	570	29	5.1
1975	4,839	839	17.4	1,512	198	13.5	556	22	4.0
1976	4,864	916	18.8	1,515	218	14.4	584	53	9.1
1977	5,521	1,192	21.6	1,619	228	14.1	638	52	8.1
1978	5,885	1,318	22.4	1,760	295	16.8	623	61	9.8
1979	6,078	1,428	23.5	1,772	326	18.4	646	58	9.0
1980	6,214	1,513	24.3	1,740	336	19.3	628	64	10.2
1981	6,644	1,697	25.5	1,844	416	22.6	582	56	9.6
1982	6,956	1,827	26.3	1,971	459	23.3	657	103	15.7
1983							637	97	15.2

Data Sources: National Center for Education Statistics and National Research Council

Master's degrees, generally the preferred degree for professional entry level, have gone up 81.8% (56% for men and 306% for women)[2] while doctorates rose 15.8% (1% for men and 547% for women) between 1971 to 1983.[6] The increase in master's degrees is well below that in bachelor's degrees, perhaps indicating (as in engineering) the excellent job opportunities and

TABLE 8

PHYSICS ENROLLMENTS AND DEGREES AWARDED BY ACADEMIC YEAR 1972-1984

Academic Year	Undergraduate Physics-Major Enrollment Juniors	Undergraduate Physics-Major Enrollment Seniors	Graduate Physics-Student Enrollment* Total	Graduate Physics-Student Enrollment* 1st Yr.	No. of Physics Degrees Granted (July 1 to June 30) Bachelor's	Master's	Doctorate
1972-73	6,012	5,806	11,804	2,904	4,923	1,961	1,445
1973-74	5,858	5,108**	11,119	2,680	4,652	1,772	1,236
1974-75	5,660	4,909**	10,410	2,668	4,571	1,650	1,167
1975-76	5,888	4,922**	10,372	2,646	4,487	1,570	1,111
1976-77	5,711	4,930**	9,991	2,624	4,517	1,469	1,051
1977-78	5,820	4,975+	9,835	2,499	4,457	1,422	971
1978-79	5,835	4,964	9,813	2,458	4,416	1,428	1,033
1979-80	5,696	4,942	9,647	2,439	4,440	1,370	912
1980-81	5,905	5,091	9,934	2,564	4,513	1,387	927
1981-82	6,386	5,372	10,173	2,637	4,558	1,476	912
1982-83	6,299	5,580	10,429	2,630	4,795	1,426	921
1983-84	6,303	5,658	10,922	2,855			

* Includes part-time students

** This total has been adjusted by 500 students who were seniors for more than one year

\+ This total has been adjusted by 300 students who were seniors for more than one year

SOURCE: American Institute of Physics

TABLE 10

ENROLLMENTS AND DEGREES IN GEOLOGY

Year	ENROLLMENTS Junior	ENROLLMENTS Senior	ENROLLMENTS Master's	ENROLLMENTS Doctorate	DEGREES Bachelor's	DEGREES Master's	DEGREES Doctorate
			TOTAL				
1976	4,305	4,130	2,876	912	3,259	935	280
1977	5,825	5,699	3,457	1,125	3,740	920	257
1978	5,857	6,210	3,815	1,034	4,189	1,126	228
1979	6,131	6,880	3,968	1,075	4,334	1,204	222
1980	6,842	7,261	4,548	1,251	5,092	1,218	258
1981	7,511	8,424	4,883	1,257	5,010	1,275	266
1982	8,009	8,756	5,060	1,116	5,337	1,411	203
1983	8,574	10,210	5,007	1,150			
			PERCENT WOMEN				
1976	21.3	19.2	17.8	10.9	18.1	13.3	7.5
1977	22.4	20.1	18.5	15.9	21.5	11.8	7.8
1978	22.4	21.2	19.0	14.8	22.2	18.1	10.5
1979	24.5	23.9	20.5	18.0	23.7	18.9	9.5
1980	25.1	24.3	22.3	19.0	25.0	20.4	12.0
1981	24.2	24.4	23.8	19.5	25.4	23.1	25.2
1982	25.1	24.6	24.7	20.0	25.7	22.9	21.2
1983	24.7	25.0	25.4	21.7			

SOURCE: American Geological Institute, National Center for Education Statistics and National Research Council

TABLE 11

CHEMISTRY DEGREES

Year	Bachelor's	Master's	Doctorate
1964-65	10,047	1,715	1,414
1965-66	9,735	1,839	1,571
1966-67	9,872	1,831	1,744
1967-68	10,847	2,014	1,757
1968-69	11,807	2,070	1,941
1969-70	11,617	2,146	2,208
1970-71	11,183	2,284	2,160
1971-72	10,721	2,259	1,971
1972-73	10,222	2,230	1,882
1973-74	10,517	2,138	1,828
1974-75	10,649	1,986	1,822
1975-76	11,107	1,796	1,623
1976-77	11,215	1,767	1,570
1977-78	11,474	1,892	1,545
1978-79	11,643	1,765	1,567
1979-80	11,446	1,733	1,538
1980-81	11,347	1,654	1,622
1981-82	11,062	1,751	1,722

SOURCE: National Center for Education Statistics

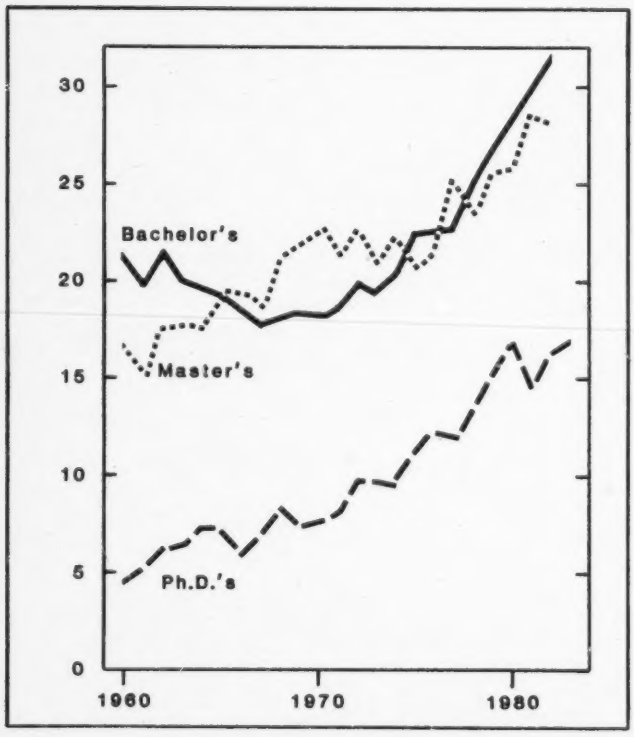

Figure 11. Percent of Chemistry Degrees Awarded to Women [Data Source: National Center for Education Statistics].

starting salaries at the lower degree level through the seventies.

Geology is the predominant field in the geo-sciences, and a comparison of geology enrollments with degrees indicates continuing increases in these degrees, at least over the next several years[11] (Table 10).

Chemistry

In chemistry, bachelor's degrees dropped in 1972 and 1973 before starting slowly up again in 1974.[2] This increase stopped in 1979, and by 1982, the number is still well below the 1969 peak (Table 11). The number of master's degrees peaked in 1971 and has remained below 2,000 per year since 1975.[2] Doctorates also peaked at the beginning of the decade, and remained below 1,600 per year until 1981.[6]

Women now earn nearly a third of the bachlor's and master's degrees, and one-sixth of the doctorates - a continuing if not always steady proportional increase at all degree levels since 1960 (fig. 11).

Mathematics, Statistics and Computer Sciences

The number of degrees in mathematics and statistics dropped so rapidly through the seventies that less than half as many bachelor's degrees were awarded in 1980 as in 1971 (fig. 12). Some, but not all of the decrease, was counterbalanced by an increasing number of graduates in computer science.[12] By 1982, the total of bachelor's degrees in these fields exceeded by 20% the number of math degrees a decade earlier.

Women have earned about two-fifths of the bachelor's, a third of the master's and one-tenth of the doctorates in mathematics and statistics through the seventies, but they are still somewhat below these proportions in computer science where job opportunities appear to be best (Table 12). In 1982, women earned 35% of the bachelor's, 26.5% of the master's and 8.4% of the doctoral degrees in computer science.[2]

Despite the drop in the size of the group, the number of degree awards in computer science probably will continue to increase for at least a few years because of the excellent job market for graduates, both present and projected. Degrees in mathematics may continue a slow drop.

Computer science departments, like those in engineering, have serious faculty shortages, precipitated by the explosive growth in the computer field. The supply of new Ph.D.s is only about 20% of the demand.[13]

TABLE 12

DEGREES IN MATHEMATICS/STATISTICS AND COMPUTER SCIENCES, 1970-1982

Year	Bachelor's Degrees				Master's Degrees				Doctoral Degrees			
	Math & Statistics		Computer Science		Math & Statistics		Computer Science		Math & Statistics		Computer Science	
	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W
1970	27,442	37.4	1,544	12.9	5,636	29.6	1,459	9.3	1,236	7.8	107	1.9
1971	24,801	38.0	1,624	14.5	5,191	29.2	1,588	10.3	1,199	7.8	128	2.3
1972	23,713	39.0	3,402	13.5	5,198	29.7	1,977	11.4	1,128	7.9	167	7.2
1973	23,067	40.2	4,305	14.9	5,028	29.9	2,113	10.6	1,068	9.6	196	7.7
1974	21,635	40.9	4,757	16.4	4,834	31.0	2,276	12.9	1,031	9.7	198	4.5
1975	18,181	41.8	5,039	18.9	4,327	32.9	2,299	14.7	975	11.3	213	6.6
1976	15,984	40.7	5,664	19.8	3,857	34.0	2,603	14.5	856	11.0	244	9.4
1977	14,196	41.5	6,407	23.9	3,695	35.2	2,798	16.7	823	13.2	216	8.8
1978	12,569	41.4	7,224	25.8	3,373	33.9	3,038	18.7	805	15.4	196	7.7
1979	12,115	41.6	8,769	28.1	3,578	33.8	3,055	18.8	730	16.7	209	12.9
1980	11,473	42.3	11,213	30.3	2,868	36.1	3,647	20.9	724	13.8	240	11.3
1981	11,078	42.8	15,121	32.5	2,567	34.1	4,218	23.0	728	15.6	252	9.9
1982	11,599	43.2	20,267	34.8	2,727	33.2	4,935	26.5	681	13.8	251	8.4

SOURCE: National Center for Education Statistics

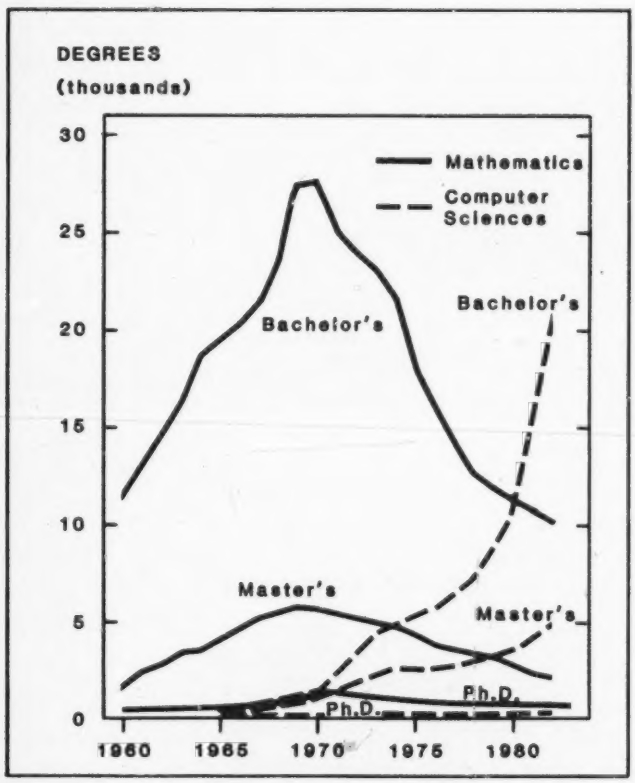

Figure 12. Degrees in Mathematics and Computer Sciences [Data Source: National Center for Education Statistics]

Life Sciences

Degrees in the agricultural sciences increased through 1979 at the bachelor's and master's level, and held fairly steady at the doctoral level through the seventies[2,6] (Table 13). However, about a third of the Ph.D.s are awarded to foreign nationals on temporary visas (Table 1).

In the biological sciences, degree production increased until 1976 at the bachelor's and master's levels, and shows a steady decrease since that year.[2] Doctorates show a drop from 1977-1978, but are rising again slowly[6] (Table 13).

As in the social and behavioral sciences and in mathematics, women earn a large and increasing fraction of the bioscience degrees. Their proportion of degrees in the agricultural sciences remained well below 5% until the seventies, but has leaped to 30% at the bachelor's level, 25% at the master's level and 14% at the doctoral level[2] (Table 13).

The projections of degrees in Table 13, were made by the National Center for Education Statistics[8] before the 1979 or later degrees were available. In every instance, bachelor's level projections for succeeding years have overestimated degree awards for men and underestimated those for women. Table 13 includes both actual degrees for 1981 and 1982 and the pro-

TABLE 13

DEGREES IN AGRICULTURAL AND BIOLOGICAL SCIENCES 1970-1982
PROJECTED TO 1989

Year	Bachelor's Degrees				Master's Degrees				Doctoral Degrees			
	Agricultural/ Natural Resources		Biological Sciences		Agricultural/ Natural Resources		Biological Sciences		Agricultural/ Natural Resources		Biological Sciences	
	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W
1970	12,382	4.1	37,031	28.0	2,197	6.3	5,800	31.5	1,004	2.8	3,289	14.3
1971	12,672	4.2	35,743	29.1	2,457	5.9	5,728	33.5	1,086	2.9	3,654	16.3
1972	13,516	5.5	37,293	29.4	2,680	7.1	6,101	33.0	971	2.7	3,653	17.0
1973	14,756	7.4	42,233	29.8	2,807	7.8	6,263	30.5	1,059	2.6	3,636	19.5
1974	16,253	9.7	48,340	31.2	2,928	9.8	6,552	30.5	930	3.5	3,439	20.3
1975	17,528	14.1	51,741	33.1	3,067	11.9	6,550	30.0	991	3.3	3,384	22.0
1976	19,402	18.3	54,275	34.6	3,340	14.3	6,582	31.7	928	6.6	3,392	21.5
1977	21,467	22.3	53,605	36.2	3,724	14.7	7,114	33.7	893	6.9	3,397	21.4
1978	22,650	24.6	51,502	38.4	4,023	18.8	6,806	35.4	971	6.4	3,309	24.1
1979	23,247	27.1	49,576	40.6	4,007	20.2	6,879	37.7	950	7.7	3,548	25.6
1980	22,903	29.6	47,111	42.4	3,987	22.4	6,536	37.1	991	11.3	3,638	26.0
1981	21,886	30.8	43,216	44.1	4,003	23.5	5,978	38.9	1,067	11.9	3,718	28.3
1982	21,029	31.3	41,639	45.3	4,163	25.2	5,874	41.7	1,079	14.3	3,743	29.1
PROJECTED												
1981	25,740	26.4	55,890	38.7	4,370	24.9	6,880	41.0	1,100	6.3	3,510	25.1
1982	26,430	26.3	57,480	39.8	4,570	25.2	7,020	41.0	1,120	6.3	3,480	24.4
1983	27,080	26.6	57,570	39.8	4,760	25.8	7,120	41.6	1,110	6.3	3,350	24.8
1984	27,550	27.2	57,080	39.9	4,850	24.9	7,160	42.2	1,100	6.4	3,250	25.2
1985	27,800	27.6	56,140	40.1	4,990	24.2	7,170	42.0	1,080	6.5	3,140	25.5
1986	27,920	28.0	55,980	39.7	5,050	24.0	7,090	42.2	1,080	6.5	3,040	26.0
1987	28,000	28.4	54,910	41.9	5,100	23.3	6,990	42.5	1,070	6.5	2,950	26.4
1988	28,070	28.3	54,870	42.9	5,100	22.4	6,760	42.0	1,070	7.5	2,850	26.7
1989	28,550	28.8	55,030	43.5	5,120	21.7	6,570	42.2	1,060	7.5	2,760	27.2

SOURCE: National Center for Education Statistics

jections made for those years in 1980. Total projections at both graduate degree levels aremuch closer, although the increasing participation of women was not forseen. Because the number of male graduates is smaller than anticipated by NCES, the total projection may continue to be near the mark.

The projected totals of bachelor's degrees in the biological and agricultural sciences are higher by 25% and 17% respectively in 1989 than in 1980. This now appears to be unlikely. Master's degrees were expected to rise 28% in the agricultural sciences, but to be essentially level in the biological sciences between 1980 and 1989. Doctoral degrees were expected to drop only a little in the agricultural sciences but to drop 24% in the biological sciences by 1989. Whether these changes occur may depend significantly on the size of the job market created by the commercialization of biotechnology, as well as the participation of foreign students in U.S. graduate schools.

Social and Behavioral Sciences

Degrees in the social and behavioral sciences (limited in this report principally to psychology, economics, anthropology, sociology and political science) increased very rapidly in the late 1960s and the early 1970s, but have been dropping in recent years[2] (fig. 13). Psychology doctorates continued to rise through 1981 but dropped in 1982 and rose again in 1983,[6] so the top of the curve has probably been reached. Economics bachelor's degrees are again rising after dropping from 1970 to 1975, but the rest of these fields continue generally downward.

Social and behavioral science degrees represented 37.2% of all science and engineering bachelor's degrees awarded in 1982[2] and 32.2% of all the S/E doctorates[6] in 1983, down from 36% in 1978. About half of all women graduates in science and engineering earn degrees in these fields. In 1982, 53% of women S/E bachelor's graduates majored in psychology or one of the social sciences. By 1983, 48% of women S/E graduates were in these fields, but this figure

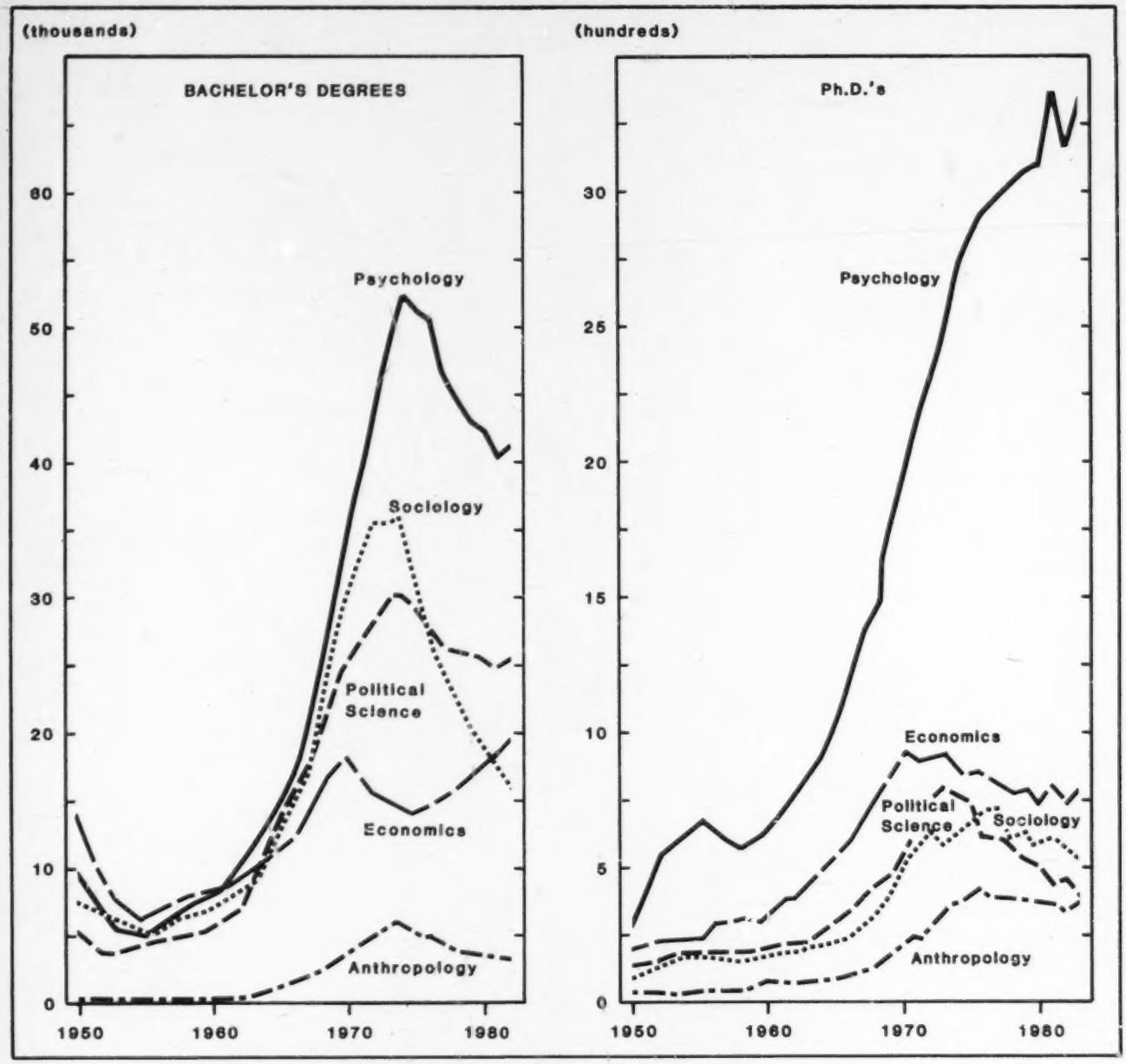

Figure 13. Degrees in the Social and Behavioral Sciences, 1950-1983
[Data Sources: National Center for Education Statistics and National Research Council]

is down from 56.5% in 1977, indicating the wider diversity of program areas being chosen by women at the doctoral level. Within the social sciences, their largest representation continues to be in psychology (where they earned 47.5% of all doctorates awarded in 1983), and their smallest representation is in economics where they earned only 16.2% of the total awarded.

Within this group of fields, only economics shows substantial proportions of foreign students. In 1983, 25.9% of doctorates earned in this field were awarded to foreign students on temporary visas[6] (Table 1).

Degree Summary

Although the total number of science and engineering degrees awarded is expected to drop through the remainder of the 1980s, some fields will drop much more slowly than others, and at least one will probably continue to rise. The number of degrees awarded in the computer sciences can be expected to continue upward throughout the decade if demand for the services of these graduates remains high. All other fields, including engineering, probably will experience some decreases by the end of

the decade. However, if the pattern of the past two decades persists in the eighties, 30 to 34 percent of all bachelor's graduates over the decade will receive their degree in a science or engineering field. The National Center for Education Statistics projects the total number of bachelor awards in 1991 to range from a low of 790,000 to a high of 1,054,000. The intermediate projection is for 922,000, bachelor's degrees[8] of which 276,000 to 313,500 should be awarded in some field of science or engineering.

The number of S/E doctorates to be awarded over the next decade is somewhat more difficult to project because it is affected not only by the number who attain bachelor's degrees in these fields, but by the job market for both bachelor's and doctoral graduates. It will also be affected by the numbers of foreign students admitted. The present shortage of U.S. doctoral candidates in engineering and computer science, for example, is not the result of low demand for these doctorates, but rather of high demand for baccalaureate level graduates in these fields through 1981. The recession of the early 1980s brought a significant drop in offers to the engineering graduating class of 1981-82, and an even sharper drop in offers to the 1982-83 graduates.[14] As was expected, graduate enrollment in engineering rose substantially in Fall 1983,[3] both because of the drop in employment opportunities for baccalaureate graduates and continuing demand for graduates with graduate degrees. The marketplace for 1984 bachelor's graduates was considerably improved over 1983, and graduate enrollment in engineering probably levelled off in 1984-85.

On the other hand, the decrease in graduate enrollments and in the number of Ph.D.s awarded in recent years in most of the social sciences probably is more related to decreasing demand for doctorates in these fields, particularly in academic institutions, than to any other factor.

The population of 30 year olds (the median age of doctorate recipients in the sciences) will not begin to decline until 1991. Thus, whether the number of S/E doctorates awarded increases or decreases over the decade will be more dependent on other factors than on the size of the age group.

NCES projects between 23,500 and 43,000 total doctoral awards in 1991, with an intermediate projection of 33,400.[8] This number represents an increase of about 7% from 1983.[6] Between 55 and 65 percent of the degrees awarded probably will be in S/E fields (figs. 6 and 9).

Immigrants

A second source of supply of scientists and engineers is immigrants from other countries. Immigrants fall into four general categories: immediate relatives, special immigrants, refugees, and quota immigrants. Immediate relatives are exempt from quota limitations. Present U.S. immigration policy allows a maximum of 170,000 persons from the eastern hemisphere nations and 120,000 from western hemisphere nations to enter the United States each year. Nations in the eastern hemisphere are limited to 20,000 for each country, but western hemisphere nations do not have specific quotas.

Preference for quota immigration has six categories. The first two, the fourth and the fifth preferences are for relatives of U.S. citizens and relatives of qualified immigrants. The third preference group is for qualified immigrants who are members of the professions, or who because of their exceptional ability in the sciences or the arts will substantially benefit prospectively in the national economy, and whose services are sought by a U.S. employer. The sixth preference is available to qualified immigrants capable of performing specified skilled or unskilled labor, not of a temporary or seasonal nature, for which a shortage of employable and willing persons exists in the U.S.

Professionals seeking to enter the U.S. to work in a specific occupation must obtain a "labor certification" showing that the Secretary of Labor has determined that the individual's entry and planned job cannot be filled with a qualified U.S. worker; and that employing the immigrant will not adversely affect the wages and working conditions of U.S. workers similarly employed. To facilitate the processing of requests for labor certification, schedules are provided which contain predeterminations made by the Secretary of Labor, and Schedule A lists occupations in short supply nationally and occupational categories which have been declared by the Secretary of Labor to be eligible for certification. The list may be revised periodically. Although engineers and some scientists were once included on Schedule A, they have not been included for several years, and thus, potential employers must go through a lengthy process of advertising a job without finding qualified U.S. applicants before obtaining permission for temporary employment of the individual.[15] About 30% of immigrant scientists and engineers have, in the past, received worker certifications.[16]

Persons may be admitted on a permanent basis, or on a temporary basis for a specific purpose such as travel or study. Those allowed to stay permanently are designated as "immi-

TABLE 14

IMMIGRANT AND NONIMMIGRANT* SCIENTISTS AND ENGINEERS: 1966-78
[in thousands]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976†	1977†	1978†
Immigrants	7.2	12.5	13.0	10.3	13.3	13.1	11.3	6.6	6.0	6.9	7.8	8.2	10.5
Nonimmigrants	5.5	5.4	5.6	5.4	6.6	2.4	2.7	4.1	4.9	5.5	6.3	6.8	4.6

† Includes computer specialists.
* Excludes students

Source: Immigration and Naturalization Service and National Science Foundation

grants" and those admitted temporarily are designated as non-immigrants or foreign nationals in this report. The numbers in both categories who entered in 1966-78 are shown in Table 14, and the 1977 and 1978 entrants are shown in more detail in Table 15.[16]

There is disagreement between various groups in the U.S. as to whether individuals admitted to the U.S. as students who complete a graduate degree here should be allowed to remain in the U.S. after completion of the degree and perhaps a short period of further training, such as for postdoctoral study and research. The number and proportion of foreign postdoctorates in U. S. doctoral institutions is shown for 1977 and 1983 in Table 16.[17]

Many employers, both in industry and in academic institutions, say that they cannot fill certain research and faculty positions with U.S. citizens. Some organizations insist that allowing such foreign nationals to work here and later to become immigrants is a brain drain from the countries of origin, and should not be allowed on those grounds. Others feel that the U.S. is a nation of immigrants, and that such applicants for permanent admission will enrich the U.S. and its technological advancement. Still others are concerned that the increasing population of foreign engineers earning degrees in this country and then finding employment here may be taking jobs at low pay in order to remain here, thus driving down salaries and reducing opportunities for U.S. members of the engineering profession. No available statistical

TABLE 15

IMMIGRANT AND NONIMMIGRANT SCIENTISTS AND ENGINEERS BY FIELD OF SPECIALIZATION: FISCAL YEARS 1976, 1977 and 1978

Field of Specialization	Immigrants			Nonimmigrants		
	1976	1977	1978	1976	1977	1978
All Fields, Total	7,782	8,189	19,455	6,446	9,829	4,580
Engineers, Total	5,146	5,191	6,762	3,478	3,779	2,566
Aeronautical	32	61	75	18	63	11
Chemical	446	470	481	189	169	146
Civil	697	543	704	158	113	63
Electrical	754	680	916	247	249	168
Industrial	190	205	263	253	14	34
Mechanical	823	676	811	191	130	104
Metallurgical and Metallurgists	72	95	86	34	19	11
Mining and Petroleum	86	130	135	104	103	33
Sales	46	59	60	34	12	13
Other	2,000	2,272	3,231	2,250	2,877	1,983
Natural Scientists, Total	1,737	1,983	2,320	2,074	1,904	1,358
Agricultural Scientists	241	314	437	352	199	167
Biologists	268	325	334	288	430	285
Chemists	678	752	868	678	578	409
Geologists and Geophysicists	119	118	131	204	193	114
Mathematicians	210	228	254	140	124	62
Physicists, Astronomers and Space Scientists	174	181	208	337	297	289
Other	47	65	88	75	83	32
Social Scientists	612	645	784	608	691	371
Economists	336	374	426	460	607	273
Psychologists	131	137	206	68	40	33
Other	145	134	152	80	44	65
Computer Specialists	287	370	599	286	455	285

Source: Immigration and Naturalization Service and National Science Foundation

TABLE 16

FOREIGN AS A PERCENT OF ALL POSTDOCTORALS IN DOCTORATE-GRANTING INSTITUTIONS IN SELECTED SCIENCE FIELDS: 1977 and 1983

Selected Fields	1977			1983		
	Total	Foreign	% of Total	Total	Foreign	% of Total
Physical Sciences	4,197	1,732	41.3	4,444	2,385	53.7
Earth, Environmental, and Marine Sciences	375	105	28.0	414	158	38.2
Biological Sciences	6,616	1,977	29.9	8,404	2,584	30.7
Mathematical Sciences†	86	39	45.3	170	90	52.9
Social Sciences§	358	97	27.1	360	117	32.5

† Excludes Computer Sciences.
§ Excludes Psychology.

SOURCE: National Science Foundation

evidence indicates that foreign engineers are paid less by U.S. employers than are U.S. engineers.

In 1984, major changes in immigration rules were proposed in legislation passed separately by both houses of Congress. Both the House and Senate versions included an exception to the general rule that foreign nationals in the U.S. on a student visa be required to return to their native countries for two years after graduation before attempting to enter the U.S. on a permanent visa. The exceptions would have allowed some scientists and engineers, as well as some other specialists, to accept employment and remain here. However, the bill failed final passage, and so the situation continues to be handled on a case by case basis.

In the 1970s, relatively few of the non-immigrant scientists and engineers in the U.S. were admitted as temporary workers performing services for which no U.S. workers were available. In 1976, only 6% of the non-immigrant entrants were in this category, and in 1978, the proportion was less than 4%. In 1978, 42% of non-immigrants were exchange visitors, 33.5% were intra-company transferees, 15% were temporary workers of distinguished merit and ability, and 5% were industrial trainees. However, many scientists and engineers who entered the U.S. in a non-immigrant status later adjusted their status to immigrant. More than 49,000 did so between 1966 and 1978.[16]

In 1976 and 1977, about half of all scientists and engineers from abroad who sought U.S. Labor Department certification were given that certification. In 1978, 76% of the 2,768 who sought such certification received it.[16] Similar data for later years are not available.

When we combine the 126,000 scientists and engineers admitted as immigrants between 1966 and 1978 and the 49,000 non-immigrants whose status was adjusted to immigrant, we find that 175,700 scientists and engineers from abroad enriched the U.S. science and engineering labor force during those years.

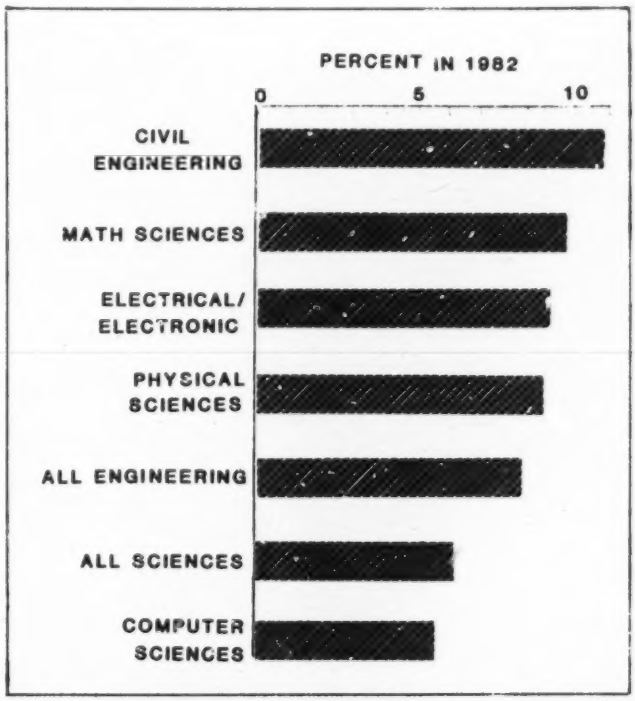

Figure 14. Proportion of 1982 U.S. Science and Engineering Labor Force Who are Foreign-Born U.S. Citizens [Data Source: National Science Foundation]

TABLE 17

EXPERIENCED SEC PERSONNEL WHO ARE U.S. CITIZENS BY FIELD AND PLACE OF BIRTH, 1982

	Total	U.S. Born	Foreign Born						No Response
			Total	Africa	Asia	Latin Am.	No. Am.†	Other	
All S/E Fields	1,788,042	1,626,415	136,226	2,897	55,650	12,926	64,107	646	25,402
All Science	564,668	519,480	36,206	1,001	13,235	3,851	17,786	333	8,982
Physical Sciences	130,100	116,373	11,898	433	5,159	619	5,666	21	1,829
Earth, Env. & Marine Sci.	44,513	42,113	1,869	11	615	299	926	18	541
Mathematical Sciences	46,075	41,102	4,507	12	1,729	457	2,309	0	466
Life Sciences	133,811	123,817	7,863	490	3,175	776	3,183	239	2,132
Social Sciences	121,842	112,679	6,965	44	2,122	1,195	3,550	54	2,198
Psychology	88,328	83,395	3,116	12	445	507	2,152	0	1,816
Engineering	1,056,587	952,398	90,333	1,706	38,131	8,025	42,157	314	13,857
Civil	148,399	129,436	16,216	286	8,521	1,488	5,853	68	2,748
Electrical/Electronic	241,245	216,189	22,471	518	9,140	1,795	10,874	144	2,584
Mechanical	212,272	189,574	13,510	406	733	1,514	10,789	68	2,590
Other	454,671	417,199	38,136	496	19,737	3,228	14,641	34	5,935
Computer Science	166,787	154,536	9,687	190	4,284	1,049	4,164	0	2,563

TABLE 18

EXPERIENCED SEC PERSONNEL WHO ARE U.S. CITIZENS BY FIELD AND PLACE OF BIRTH, 1982

	Total	U.S. Born	Foreign Born						No Response
			Total	Africa	Asia	Latin Am.	No. Am.†	Other	
All S/E Fields	1,788,042	1,626,415	136,226	2,897	55,650	12,926	64,107	646	25,402
All Science	564,668	519,480	36,206	1,001	13,235	3,851	17,786	333	8,892
Physical Sciences	130,100	116,373	11,898	433	5,159	619	5,666	21	1,829
Earth, Env. & Marine Sci.	44,513	42,113	1,869	11	615	299	926	18	541
Mathematical Sciences	46,075	41,102	4,507	12	1,729	457	2,309	0	466
Life Sciences	133,811	123,817	7,863	490	3,175	776	3,183	239	2,132
Social Sciences	121,842	112,679	6,965	44	2,122	1,195	3,550	54	2,198
Psychology	88,328	83,395	3,116	12	445	507	2,152	0	1,816
Engineering	1,056,587	952,298	90,333	1,706	38,131	8,025	42,157	314	13,857
Civil	148,399	129,436	16,216	286	8,521	1,488	5,853	68	2,748
Electrical/Electronic	241,245	216,189	22,471	518	9,140	1,795	10,874	144	2,584
Mechanical	212,272	189,574	13,510	406	733	1,514	10,789	68	2,590
Other	454,671	417,199	38,136	496	19,737	3,228	14,641	34	5,935
Computer Science	166,787	154,536	9,687	190	4,284	1,049	4,164	0	2,563

† Includes Europe and Soviet Union.

SOURCE: Division of Science Resources Studies/NSF; Bureau of Census.

More than one in ten of the persons in the 1982 U.S. S/E labor force (197,250) is foreign born, including many (almost eight percent) who are U.S. citizens.[17] The concentration of foreign-born citizens was greatest in civil engineering, as shown in figure 14. About one third of the foreign born scientists were from Asia, and among foreign-born engineers and computer specialists, about 42% each were Asian, as shown in Table 17.

The U.S. labor force also included about 63,500 foreign citizens in 1982, including some born in the United States. Almost half of this group were born in Asia (Table 18).

Foreign citizens who earn doctorates in science or engineering in U.S. universities have, over the years, become an increasing proportion of new entrants to the U.S. doctoral labor force, particularly in engineering, mathematics and physics. By 1983, 34.2% of new engineering Ph.D.s in the U.S. labor force were non citizens on temporary visas, as were 22.3% of new labor force entrants in mathematics and 19.7% of those in physics.[6] As shown in Table 19, the proportion of new entrants who were foreign nationals on temporary visas stayed generally steady from 1959 to about 1967, increasing substantially after that time in almost all S/E fields.

TABLE 19

DOCTORATE RECIPIENTS ENTERING THE U.S. LABOR FORCE BY CITIZENSHIP AND FIELD OF STUDY, 1959-1983

Citizenship Status	YEAR OF DOCTORATE											
	1959	1963	1965	1967	1969	1971	1973	1975	1977	1979	1981	1983
Total All Fields	**9,213**	**12,728**	**16,340**	**20,403**	**25,743**	**31,867**	**33,755**	**32,951**	**31,717**	**31,237**	**31,345**	**31,190**
Total, U.S. Location	8,517	11,678	14,922	18,875	23,833	29,254	31,189	30,508	29,440	28,946	28,925	28,716
Non-US. Perm. Visas	3.2	2.3	2.9	3.6	4.3	5.7	5.9	5.2	4.3	4.3	4.2	4.1
Non-US.Temp. Visas	3.9	5.4	6.0	6.0	5.1	4.2	4.7	6.2	6.2	6.5	7.5	9.1
Physics & Astronomy	**516**	**817**	**1,046**	**1,312**	**1,461**	**1,738**	**1,589**	**1,300**	**1,150**	**1,108**	**1,015**	**1,042**
Total, U.S. Location	473	748	954	1,209	1,325	1,524	1,436	1,176	1,044	1,010	925	922
Non-US. Perm. Visas	4.2	2.7	3.2	5.0	4.2	7.1	7.8	8.5	7.6	6.5	5.6	5.1
Non-US Temp. Visas	6.6	9.6	9.6	9.1	7.2	7.7	10.9	14.1	13.9	14.1	16.9	19.7
Chemistry	**1,054**	**1,288**	**1,444**	**1,773**	**1,967**	**2,211**	**1,855**	**1,776**	**1,571**	**1,566**	**1,612**	**1,759**
Total, U.S. Location	980	1,203	1,335	1,643	1,841	2,000	1,728	1,652	1,481	1,481	1,517	1,648
Non-US. Perm. Visas	2.8	1.8	2.5	3.0	4.7	7.8	10.0	7.4	6.8	6.3	6.1	4.1
Non-US. Temp. Visas	5.2	7.8	8.5	9.2	6.6	5.4	6.9	9.3	9.8	10.5	12.1	13.4
Mathematics	**289**	**483**	**685**	**830**	**1,070**	**1,238**	**1,232**	**1,147**	**933**	**769**	**728**	**701**
Total, U.S. Location	271	451	639	783	999	1,150	1,100	1,033	852	708	650	619
Non-US. Perm. Visas	3.3	2.0	2.2	3.1	4.5	5.1	6.7	7.0	6.3	6.9	6.2	6.8
Non-US. Temp. Visas	6.3	9.3	6.9	9.3	7.0	8.3	8.4	10.4	11.4	14.0	18.8	22.3
Engineering	**699**	**1,357**	**2,074**	**2,604**	**3,265**	**3,498**	**3,364**	**3,002**	**2,643**	**2,490**	**2,528**	**2,780**
Total, U.S. Location	643	1,238	1,891	2,419	3,054	3,147	3,030	2,713	2,392	2,214	2,220	2,391
Non-US. Perm. Visas	9.2	5.0	5.6	7.6	10.1	15.1	17.1	15.1	13.2	14.1	13.2	12.8
Non-US. Temp. Visas	9.6	10.5	10.3	11.5	10.1	9.0	12.0	21.0	23.2	26.0	29.7	34.2
Biological and Health Sciences	**1,239**	**1,617**	**2,108**	**2,537**	**3,389**	**4,195**	**4,134**	**3,959**	**3,995**	**4,214**	**4,457**	**4,368**
Total, U.S. Location	1,092	1,427	1,814	2,280	3,053	3,825	3,801	3,629	3,708	3,896	4,136	4,075
Non-US. Perm. Visas	3.8	2.5	3.0	3.7	4.2	5.5	6.8	5.9	5.4	4.1	3.6	3.4
Non-US. Temp. Visas	5.5	8.8	9.5	8.5	7.1	4.6	4.5	5.3	5.3	4.6	4.7	6.0
Agricultural Sciences	**342**	**466**	**576**	**606**	**815**	**1,073**	**1,033**	**1,067**	**925**	**1,009**	**1,150**	**1,172**
Total, U.S. Location	282	387	445	454	647	830	795	820	695	763	860	889
Non-US. Perm. Visas	1.8	1.6	3.1	1.1	4.2	8.2	9.8	8.5	3.9	4.3	4.7	4.3
Non-US. Temp. Visas	8.9	7.0	13.0	12.1	14.5	10.1	11.4	13.3	15.7	14.3	15.3	13.7
Social Sciences	**1,644**	**2,027**	**2,327**	**3,102**	**3,984**	**5,189**	**5,758**	**6,066**	**6,073**	**5,961**	**6,142**	**6,055**
Total, U.S. Location	1,537	1,850	2,124	2,835	3,658	4,758	5,284	5,605	5,643	5,576	5,767	5,716
Non-US. Perm. Visas	3.8	2.9	3.0	3.8	3.5	4.5	4.0	3.4	3.1	3.0	3.1	3.2
Non-US. Temp. Visas	2.9	3.2	4.6	4.0	3.9	3.4	4.0	4.3	4.1	4.1	4.4	5.1

NOTE: Details may not add to totals because of rounding.

SOURCE: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File

TABLE 20

ESTIMATED 1 YEAR INFLOW OF FOREIGN NATIONAL SCIENTISTS AND ENGINEERS TO THE U.S. LABOR MARKET, 1981
(Excluding Permanent Residents)

Employment Field	No U.S. Degree	Degree From An U.S. University	Total
Engineers	**1,990**	**7,332**	**9,322**
Ph.D.	209	475	684
B.S./M.S.	1,781	6,857	8,638
Scientists	**1,338**	**5,682**	**7,020**
Ph.D.	302	553	855
B.S./M.S.	1,036	5,129	6,165

SOURCE: Michael Finn, Oak Ridge Associated Universities

However, we cannot be certain whether these data would change substantially if the survey presently conducted one year after receipt of the doctorate for each class were, instead, to take place two years afterward. This is because the employment situation for those who hold student visas may be dependent on U.S. immigration regulations in the year following the doctorate. Generally, a temporary visa holder may remain in the U.S. for practical training for one year following graduation under an exchange visitor or J visa, while remaining after that period requires the more difficult process of obtaining an H, or temporary worker visa. Thus, although many temporary visa holders may stay in the U.S. immediately following graduation and be classified as new entrants to the U.S. labor force in these NRC data, there may be a substantial out-migration of these same individuals a year later. Nonetheless, individuals from other nations who obtain doctoral degrees from U.S. institutions do constitute an important and growing segment of the total U.S. doctoral labor force, particularly in some S/E fields.

Recent research by Michael Finn[18] estimates the one year inflow of foreign national scientists and engineers to the U.S. labor market in 1981 to include 9,322 engineers and 7,020 scientists, most of them with degrees from U.S. universities, as shown in Table 20. This table includes recent graduates who are working in non-S/E occupations. Removing this group would reduce the estimates by 830 B.S./M.S. engineers and 727 B.S/M.S. scientists.

The National Science Foundation estimates that in 1981, about 2,300 of the scientists in the U.S. labor force were new immigrants, as were 7,000 of the engineers and 800 of the computer specialists. In one scenario, those numbers are expected to rise to 3,000, 7,000 and 1,400 respectively by 1987[20] (Table 21). As a proportion of the total supply, however, these numbers represent less than one half of one percent of the total in either year. Compared with new entrants, their numbers also are small. Thus, although immigrant scientists make up a very important segment of the U.S. science and engineering labor force, it is also a relatively small segment.

Transfers

Many scientists and engineers trained in one field of science or engineering transfer into another during their working lives, although relatively few persons enter science or engineering fields from disciplines outside of science and engineering. Even at the doctoral level, the number of such intrafield transfers is quite large.[4] For example, as shown in Table 22, only 57.9% of those who earned doctorates in physics are working in this field; while 18.1% are employed in engineering. About one eighth of those trained in mathematics are employed as computer scientists, and there is a large cross transfer within the life sciences among those with degrees in agricultural sciences, biological sciences and medical sciences. Social science

TABLE 21

SUPPLY AND ITS COMPONENTS*, 1981 AND 1987
(in thousands)

	Scientists		Engineers		Computer Specialists	
	1981	1987	1981	1987	1981	1987
Total Supply	**573.0**	**1,047.5**	**1,123.7**	**1,507.5**	**434.9**	**465.6**
New Entrants	85.0	94.8	63.5	69.2	9.9	14.3
Attrition	9.7	19.2	23.5	29.1	8.6	9.2
Immigration	2.3	3.0	7.0	7.0	0.8	1.4

* Based on a net mobility model, and assuming high economic growth and high defense expenditure scenario.

SOURCE: National Science Foundation

TABLE 22

FIELD MOBILITY OF EMPLOYED DOCTORAL SCIENTISTS AND ENGINEERS, 1983

1983 Field OF Employment	Total Employed*	FIELD OF DOCTORATE										
		Math	Comp Sci	Phys/ Astron	Chem	Envir	Engr	Agric	Med Sci	Biol	Psych	Soc Sci
ALL FIELDS	**361,700**	**19600**	**2600**	**30300**	**50000**	**12900**	**57500**	**18900**	**14700**	**69500**	**51300**	**60000**
Mathematics	13,700	**65.5**	2.3	0.9	0.2	0.3	0.6	0.3	0.1	0.4	0.3	0.6
Comp. Sci	10,700	11.5	**79.9**	5.3	1.7	0.8	3.5	0.5	0.5	0.7	1.7	1.4
Phys/Astrn	19,400	0.9		**57.9**	1.8	1.1	1.9	0.2	0.8	0.4		
Chemistry	34,200			0.7	**68.7**	1.3	0.8	1.2	1.8	2.1		0.1
Earth/Environ	15,500	0.7		3.0	2.4	**82.0**	2.1	2.1	0.4	2.1		0.9
Engineering	56,000	6.0	9.9	18.1	7.3	4.1	**79.6**	1.5	0.6	0.8	0.7	0.4
Agric Sci	15,600	0.1		0.1	0.6	1.0	0.2	**69.8**	0.2	3.5		1.3
Medical Sci	21,600	0.4		1.2	3.3	0.6	0.9	1.4	**69.5**	11.7	2.5	1.5
Biol Sci	53,000	2.3		0.8	4.8	1.9	0.5	11.9	16.2	**70.2**	2.0	0.3
Psychology	39,700	0.2	0.4						0.7	0.1	**80.5**	1.2
Social Sci	40,300	1.1	0.5	0.6	0.3	0.3	0.2	2.8	1.1	0.2	1.9	**67.9**
Non-S/E	23,600	4.9	1.7	5.0	4.2	3.1	4.5	4.4	4.1	3.7	6.0	17.4
No Report	18,400	6.4	5.3	6.2	4.7	3.6	5.1	3.9	4.0	4.1	4.2	7.1

* Includes postdoctoral appointees as well as full-time and part-time employed doctorates

SOURCE: National Research Council

doctorates are more likely than those in other science or engineering fields to be employed outside of science or engineering. However, almost all fields employ fewer doctorates in 1983 than the number in the labor force who have doctorates in that field. The exceptions are the computer sciences, earth/environmental scien-ces, and the agricultural sciences.

At lower degree levels, employment outside of science or engineering is common, and indeed, in some degree fields, predominant over science and engineering employment (fig. 4). Transfer into science and engineering employment after a non-S/E bachelor's degree and without further formal education is rare.

Upgrading

Very few scientists enter scientific employment without at least a bachelor's degree. Those few presently in the labor force who have no degree are generally older persons who entered the labor force many years ago and have acquired knowledge and skills on the job.

Upgrading is more common in engineering, where 17.7% of employed engineers in 1982 do not have a bachelor's, master's or doctoral degree![9] Again, the majority of such workers are older men who began their employment as technicians and moved up into engineering jobs.

THE PRESENT SUPPLY

What is the total supply of scientists and engineers in the United States? This seemingly simple question, often asked of manpower specialists, is not simple at all, and the answer is uncertain.

Determining the size of the science and engineering manpower pool first requires defining the population to be counted. Many persons who earn a bachelor's degree in science or engineering never enter that manpower pool, moving immediately from the bachelor's degree into something else.

The National Science Foundation utilizes three criteria to determine whether an individual is to be counted as a scientist or engineer. Individuals are assumed to belong in the pool if they possess two or more of the following qualifications: (1) highest degree in science or engineering, (2) current or most recent employment in a science or engineering job, and (3) self-identification as a scientist or engineer. These criteria are somewhat more likely to exclude women than men from the pool, because, regardless of field of degree, women are somewhat less likely than men to find science and engineering employment (fig. 4). NSF reports that 77.1% of women in the S/E labor force and 87.4% of men were employed in science or engineering jobs in 1982.[19] Thus, almost two of every eight women and one of every eight men in the S/E labor pool statistics was included because they identified themselves as scientists or engineers, in addition to holding one or more degrees in these fields.

However, among all S/E graduates who are employed outside of science and engineering, a significant fraction ultimately identify themselves in relation to their current employment rather than to their field of degree.

TABLE 23

EMPLOYMENT SECTOR OF U.S. SCIENTISTS AND ENGINEERS, 1982

FIELD	Total Employed*	Business/ Industry	Educ. Inst.	Non-Profit Orgs	Fed. Gov't
Scientists and Engineers, Total	**3,253,000**	**2,186,400**	**391,800**	**109,800**	**284,400**
Scientists, Total	**1,405,700**	**712,300**	**341,100**	**85,600**	**152,900**
Physical Scientists	227,400	135,800	48,400	8,900	24,000
Chemists	154,100	106,100	26,900	3,700	10,300
Physicists/Astronomers	47,600	17,200	17,500	3,500	8,200
Other Physical Scientists	25,600	12,600	4,000	1,800	5,500
Mathematicians & Statisticians	79,400	26,300	37,300	2,100	10,800
Computer Specialists	299,000	237,100	16,800	8,400	20,800
Environmental Scientists	87,200	54,200	10,800	900	14,900
Earth Scientists	73,600	50,800	7,800	400	9,600
Oceanographers	3,400	600	1,300	200	1,200
Atmospheric Scientists	10,300	2,900	1,700	300	4,000
Life Scientists	337,100	110,300	109,800	21,200	57,100
Biological Scientists	233,800	71,600	75,300	14,200	45,800
Agricultural Scientists	73,800	33,800	18,700	2,300	9,200
Medical Scientists	29,500	5,000	15,800	4,600	2,100
Psychologists	138,400	45,300	52,200	26,000	3,300
Social Scientists	237,200	103,200	65,700	18,100	22,100
Economists	103,100	53,300	21,800	3,100	14,800
Sociologists/anthropologists	57,000	21,300	20,300	4,700	2,400
Other Social Scientists	77,200	28,600	23,600	10,300	4,900
Engineers, Total	**1,847,200**	**1,474,200**	**50,700**	**24,200**	**131,600**
Aeronautical/astronautical	80,800	59,800	2,300	1,000	13,300
Chemical	107,700	97,200	2,900	1,300	2,900
Civil	258,200	157,200	5,700	1,600	24,300
Electrical/electronics	437,700	354,000	13,300	7,500	38,900
Industrial	113,100	100,200	1,900	1,300	4,400
Materials	39,200	33,400	2,300	400	2,000
Mechanical	357,900	310,500	10,100	4,000	18,100
Mining	14,200	12,100	600	100	600
Nuclear	18,200	12,200	500	500	3,300
Petroleum	27,700	24,400	200	100	800
Other Engineers	392,500	313,100	10,800	6,400	22,900

*Includes those employed in all other sectors
Source: National Science Foundation

These individuals will have been dropped out of the survey population. This is one reason why the size of the science and engineering pool as reported by NSF (3.506 million) is only two thirds as large as the number of persons who have earned one or more degrees in science or engineering since 1960 (5.142 million).[2,6,19] The 407,400 women in the S/E labor force in 1982 represent only 27% of all women who earned one or more S/E degrees between 1960 and 1982.

It is easy to see how this occurs. For example, a woman with a degree in chemistry who, unable to find a job in chemistry, accepts employment in a secretarial position, will be counted in the NSF data as an employed scientist working in a non-S/E job if she self-identifies as a chemist. However, if she self-identifies as a secretary, she will be dropped from the survey population. More than 50,500 women earned bachelor's degrees in chemistry between 1960 and 1982, but NSF reports only 21,100 women chemists in the 1982 pool. About 180,200 men earned bachelor's degrees in chemistry during that same period, and NSF reports 149,700 men in the chemistry pool. Thus, the number of men chemists reported in the 1982 pool is equal to 82% of the number of chemistry bachelor's degrees awarded to men over those 22 years, while the number of women chemists reported in the pool represent only 42% of the bachelor's degrees earned by women. Some but not all of the difference is because a higher proportion of men than women earn advanced degrees in chemistry.

Other data bases result from employer or institutional responses rather than direct surveys of individual scientists and engineers. Much of the labor force data reported by the Bureau of Labor Statistics (BLS) is based on reports from employers, while degree data reported by the National Center for Education Statistics is provided by colleges and universities. These data do not necessarily match data reported by the NSF. In 1982, for example, BLS reported 133,000 chemists employed including 27,000 women (20.3% of the total).[21] The NSF data for that year show 158,300 chemists in the labor force of whom only 11.8% are women.[19]

These kinds of differences appear across various data sets, not only because of definitional differences and differences in the reporting source of the data, but also differences in sampling procedures.

The Bureau of Labor Statistics says that there were 1,572,000 engineers, 357,000 life and physical scientists, and 261,000 social/behavioral scientists employed in 1983.[21] However, college and university teachers are listed separately and are not reported by field. If these numbers were included, the totals would be higher.

The most recent data available from the National Science Foundation[19] show that in 1982 the number of employed engineers was 1,847,200, life and physical scientists 651,700, and social/behavioral scientists 375,600. When all scientists and engineers employed in educational institutions are dropped out, the NSF data show 1,796,100 engineers, 806,800 life scientists and 257,700 social and behavioral scientists remaining.

It is apparent then that the total number of scientists and engineers in the U.S. labor force cannot be stated with certainty. The number of U.S. scientists and engineers in 1982, as estimated by the National Science Foundation, is shown in Table 23 by employment sector and field.

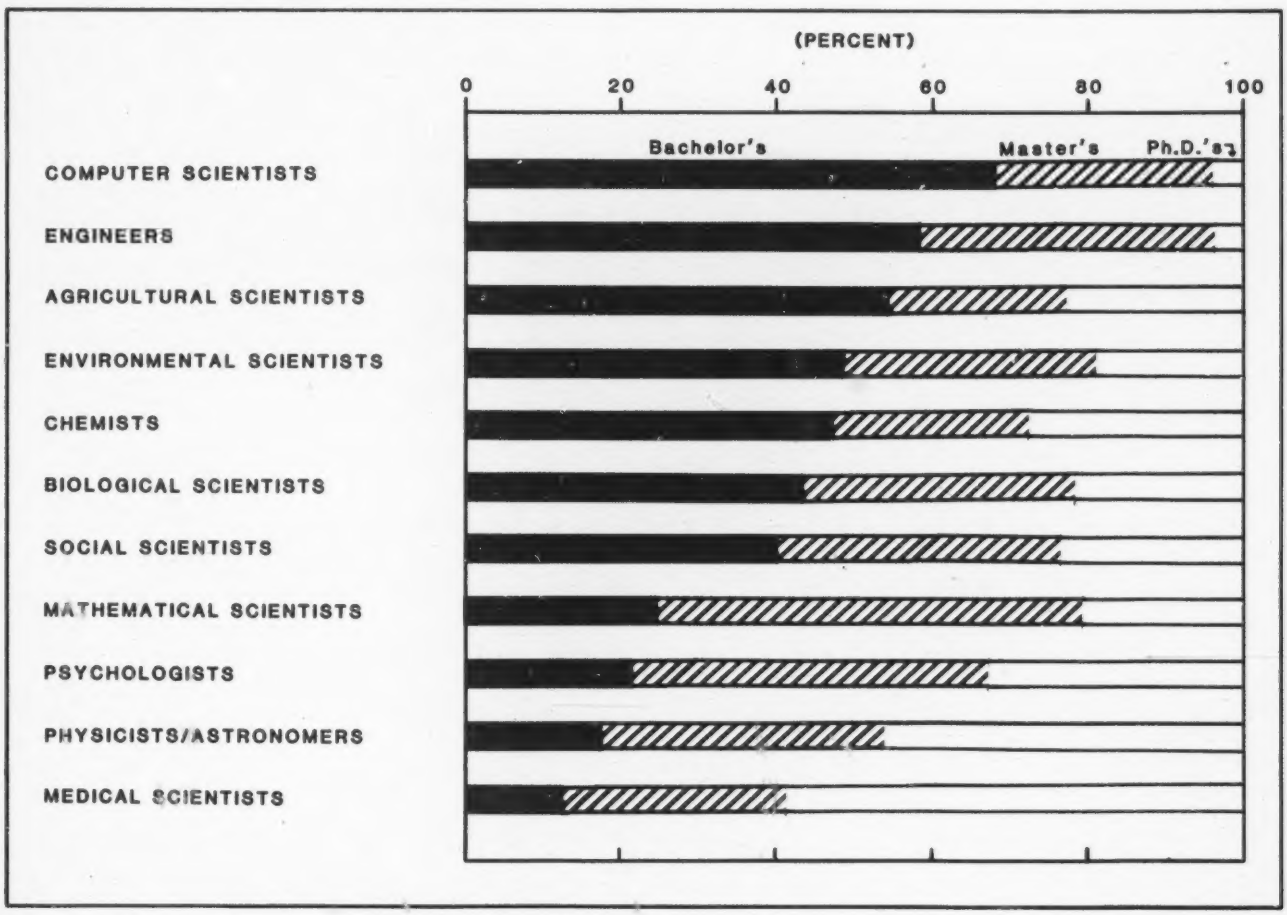

Figure 15. Highest Degree Level of Scientists and Engineers
[Data Source: National Science Foundation]

The general science and engineering population varies widely in the level of formal education achieved. In 1982, the proportion with doctorates ranged from 3% of computer specialists and 3.2% of engineers to 46.0% of physicists and astronomers and 58.3% of medical scientists (fig. 15). Computer scientists, engineers and agricultural scientists were the most likely to have only a bachelor's degree, while physicists, astronomers and medical scientists were least likely to have stopped their formal education at that level.[19]

The educational level of the science and engineering population is rising in most fields, and probably will continue to increase through the 1980s.

The doctoral workforce in science and engineering is of special interest in relation to academic and research activities. Most of the faculty in U.S. universities have doctorates, and Ph.D.s direct most of U.S. research activities, whether carried out in academic institutions, government, or business and industry.

A sample of the doctoral population has been surveyed biennially by the Office of Scientific and Engineering Personnel of the National Research Council since 1973.[4] The number of employed doctorates in science and engineering has increased from 262,991 in 1975 to 361,700 in 1983, a net increase of 37.5% in eight years, or about 4.7% per year. By field of employment, the largest proportional increases, particularly in recent years, have been in computer science and engineering, plus a significant increase in the group of scientists and engineers who are employed in non-science areas. Whether the rate of growth will continue in the same pattern across fields over the coming decade is not certain.

DEMAND

Demand for scientists and engineers, either present or future, can be defined in several ways, and no single definition is common across the statistical data available. Is present demand exactly equal to the number of persons employed in any particular field? Is demand a combination of the number employed plus the number of unfilled openings? Must those openings have remained unfilled for some specified period of time?

Also uncertain is the most appropriate method for assessment of imbalance between supply and demand. Would supply and demand be in perfect balance if the unemployment rate among scientists and engineers were zero and all authorized positions were filled, or would perfect balance require that all qualified scientists and engineers who wanted employment in science and engineering jobs be so employed? When there is a low but existing unemployment rate, plus a significant fraction of scientists and engineers employed in non-S/E jobs, plus a large number of advertised but unfilled S/E jobs - a combination which existed in late 1981 - are supply and demand in or out of balance? If they are out of balance, is the problem one of oversupply of scientists and engineers, undersupply of science and engineering employment, or a combination of both which varies by science or engineering field?

The problem of determining balance in supply and demand is compounded by the fact that there are different markets for experienced and inexperienced scientists and engineers. These two markets operate differently and often independently, employing different recruitment methods and different employment techniques. It is not uncommon for a company to be actively recruiting new science and engineering graduates even as they are laying off some experienced scientists and engineers. Among the principal reasons for this dichotomy is that different kinds of jobs are involved in the two markets.

New scientists or engineers are needed for entry level positions with high technical content, and for management training. Openings for experienced engineers and scientists usually are more specific in terms of job requirements, particularly on the technical side. Older scientists and engineers sought for management positions may be required to have extensive experience in a particular industry or product area.

Additional factors that enter the hiring picture are the relative differences in the cost of employing new graduates compared with those who have several years of experience; and the adaptability of new graduates, not only in terms of technical work placement but in their easier ability to make geographic shifts. Thus, the job market for new graduates is often out of phase with that of experienced scientists and engineers. This is more likely to produce career instability in some fields than in others, and may be a factor in the choices made by entering students.

The unemployment problems of older engineers, physicists and chemists in the early part of the 1970s had an obvious impact on the career choices of young people which showed up in falling enrollments in physical sciences, and for shorter times in engineering, during a decade of generally rising enrollments.

Demand for New Graduates

Several long-term ongoing surveys measure relative demand for new graduates. The College Placement Council (CPC) reports three times in each year, with final reports in July on the number and size of job offers made to graduating students at selected schools.[14] Once a year, CPC reports the actual number of hires in the previous recruiting year plus the number of positions that are expected to be available over the coming year in a broad sample of employers in business, industry, government, and non-profit and educational institutions.[22] Teaching positions are not included. This annual report compares the number of hires in the previous year with those expected for the present year in four broad discipline categories at all degree levels: engineering, science-math-other technical, business, and other non-technical. The October 1984 survey reports that 399 employers in the private sector that responded to the survey anticipate increased hiring in 1985 in three of the four curricular areas surveyed, with a slight drop in hires anticipated for the "other non-technical" graduates. The anticipated increase in engineering hires ranges from 7% at the bachelor's level and 25% at the master's level to 35% at the doctoral level, for an overall increase of 10%. However, this increase follows a drop in the hiring of new bachelor's graduates between 1981-82 and 1982-83, and an increase in hiring reported by companies for the 1983-84 class.

In the "science, math and other technical" group, companies reported a small planned increase in hiring between 1982 and 1983, with the increase growing larger in each of the two succeeding years. This group includes graduates in computer science.

A second survey, conducted annually for 39 years by the Placement Office at Northwestern University[23] reports on trends in the employment of college and university graduates for the year, from survey responses collected in October and November of the previous year. The Northwestern Endicott Survey of the employment intentions of 250 medium-sized and large U.S. corporations found that employers expect to hire 15% more bachelor's degree graduates and 13% more master's graduates in 1985 than in 1984. Openings for engineering graduates were up 18% at the bachelor's level and 22% at the master's level. Demand for computer science graduates is up 11% among these employers. This survey found an anticipated increase in hiring for science and engineering graduates from 1980 to 1981, which did occur. A drop in 1982 was followed by an even more severe drop in 1983. 1984 saw an increase in hires anticipated by these companies, with further increases projected for 1985.

In 1982, Frank Endicott conducted a survey of 112 companies to obtain estimates of long range needs for graduates with technical degrees.[24] These employers anticipated a 25% increase in the number of employees with degrees in their companies from 1982 to 1987, with a 31% increase in the number of technical degree employees and a 16% increase in the number of those with non-technical degrees. Estimating on out to 1992, 45 of the companies estimated an increase of 41% over 1982 in total graduates employed, including a 47% increase in technical graduates and a 32% increase in non-technical graduates.

Among these companies, 64% reported experiencing shortages in recent years, and 52% anticipated shortages of some kinds of graduates in 1987. The largest anticipated shortages were in engineering (particularly electrical, electronic, mechanical and metallurgical) and computer science.

The National Science Foundation has asked a selected group of employers about their technical recruiting in an annual survey conducted since 1981.[25] In 1981, fairly extensive

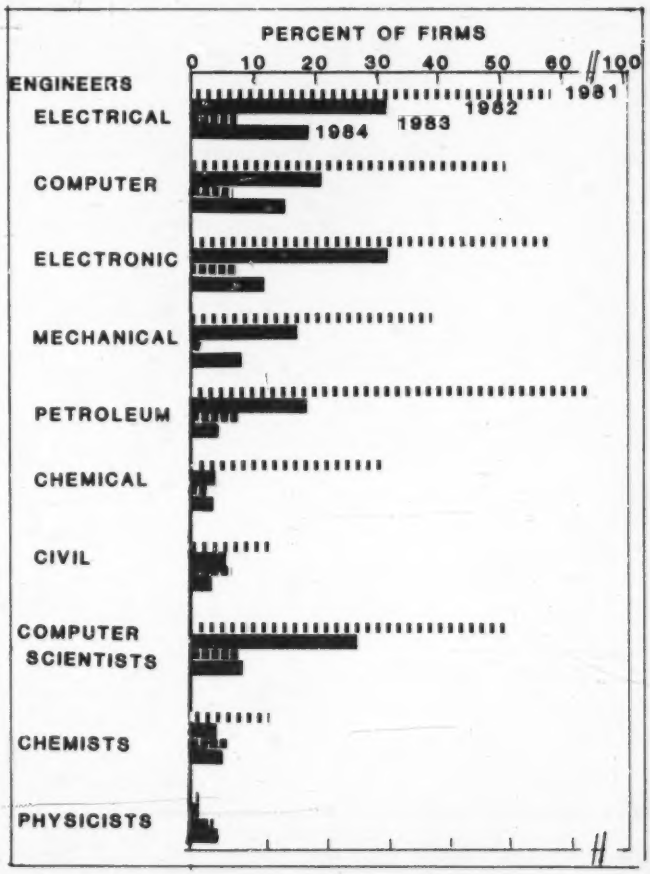

Figure 16. Firms Reporting Shortages
[Data Source: National Science Foundation]

shortages were reported in several engineering fields as well as for computer specialists. In the sciences, only chemistry appeared to have a shortage of as much as ten percent. The proportion of companies reporting shortages in these areas dropped in 1982 and again in 1983. The results of the fall 1984 survey revealed that personnel shortages had increased in some of the engineering fields over the relatively low levels of 1983, although no significant shortages were reported for either scientists or computer specialists, and in no instance did the shortage situation reach the level of severity that existed in 1981 (fig. 16).

Most of the reported shortages revealed in the 1983-84 recruiting year continued to be for experienced scientists and engineers. About two-thirds of the shortages reported in most fields were for experienced personnel, and in no case did the proportion of shortages for new graduates exceed one-half of the total. Reflecting the impact of increased defense spending, firms with a high proportion of their technical employees engaged in defense-related work reported higher levels of demand and shortages than did firms in nondefense work.

When asked to project plans for hiring science, engineering or computer (SEC) personnel in the next twelve months, these employers indicated "high" demand for computer engineers and electrical engineers, and anticipated a shortage in these fields in 1985. High demand also was anticipated for biologists and biochemists, but no shortage was foreseen in these fields. A high demand field was defined as having a ratio above 10 percent of planned new hires relative to current employment for that field.

Two annual surveys of the plans of physics graduates, conducted by the American Institute of Physics identify the career goals of graduates at three degree levels and single out the employment-oriented graduates. In order to allow at least six months for degree recipients to find positions, the employment survey is carried out in December of each year and focuses not only on descriptions of initial employment, but also on how long it took each graduate to obtain such employment. In the December 1983 survey, AIP found that more physicists secured potentially permanent employment in a shorter time than in previous years, and that more doctoral physicists found permanent employment in the subfield of their dissertations than had been true in earlier years.[26]

The 1982-83 Graduate Student Survey shows little change from previous years in the demand for new physicists at the master's and doctoral levels (fig. 17).[27]

Comparable information on the placement of new graduates in other fields is not available. However, the NSF studies of employment characteristics of recent graduates[5] indicate that 1982 unemployment rates among recent science and engineering graduates at the bachelor's level averaged 5.1% for men and 7.7% for women. At the master's level, 2.3% of the male and 7.3% of the female graduates in science and engineering reported themselves as unemployed and seeking employment (Table 24). There is a significant difference in unemployment rates by field of degree, but the higher unemployment rates for women are consistent across almost all fields at both degree levels. Table 24 also indicates considerable employment outside of S/E among these recent graduates, particularly among those in the social and life sciences.

Starting salaries, another indicator of demand, show that engineers (except civil engineers) continue to top all bachelor's degree graduates in terms of beginning salaries, with

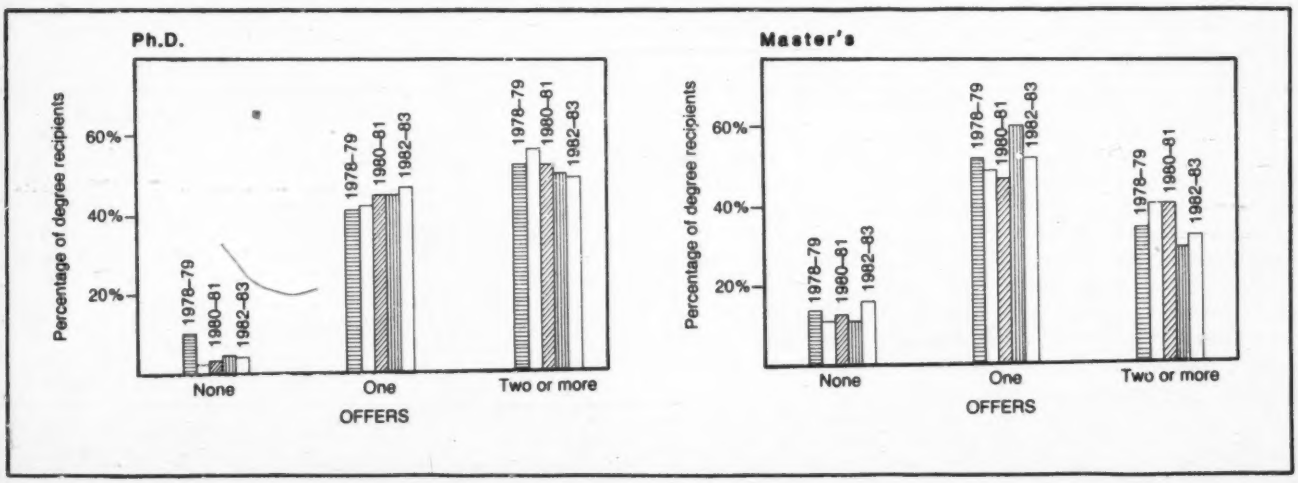

Figure 17. Employment Offers for New Physics Graduates [Source: American Institute of Physics]

TABLE 24

RATES OF LABOR FORCE PARTICIPATION, SCIENCE AND ENGINEERING UTILIZATION AND UNEMPLOYMENT AMONG RECENT SCIENCE AND ENGINEERING DEGREE RECIPIENTS, BY FIELD, SEX AND DEGREE LEVEL, 1982

FIELD AND DEGREE LEVEL	LABOR FORCE PARTICIPATION RATES		SCIENCE/ENGINEERING UTILIZATION RATES		UNEMPLOYMENT RATES	
	MEN	WOMEN	MEN	WOMEN	MEN	WOMEN
B A C H E L O R'S						
All Fields	97.0	92.2	64.5	42.4	5.1	7.7
Physical Scientists	95.7	93.6	69.8	74.9	5.9	6.2
Mathematical Scientists	95.8	94.5	71.2	63.5	5.3	2.9
Computer Specialists	99.7	96.4	87.9	92.7	0.8	3.4
Environmental Scientists	95.2	95.1	77.0	65.8	6.9	11.3
Engineers	98.4	97.5	85.9	84.0	2.8	4.7
Life Scientists	95.3	90.5	58.3	49.1	5.6	10.3
Psychologists	97.5	91.2	30.7	20.2	8.9	5.8
Social Scientists	95.8	92.1	34.6	27.1	7.9	9.3
M A S T E R'S						
All Fields	97.6	95.2	75.8	59.0	2.3	7.3
Physical Scientists	96.2	*	66.4	*	1.2	*
Mathematical Scientists	96.9	96.6	66.9	76.0	2.9	6.5
Computer Specialists	99.6	97.4	84.0	91.6	0.4	1.4
Environmental Scientists	97.2	*	83.0	*	6.5	*
Engineers	98.2	95.0	86.0	76.7	2.1	2.2
Life Scientists	95.7	96.4	74.2	67.4	2.8	1.9
Psychologists	98.4	98.7	49.4	34.6	1.7	15.2
Social Scientists	97.2	91.1	56.1	36.9	3.6	12.6

* Too few cases to estimate
SOURCE: National Science Foundation

computer science graduates next (Table 25). At the higher degree levels, this is also true.[14]

The approximate percentage distribution of job offers and of hires in the companies reporting to the College Placement Council surveys in 1984[14,22] is compared with the proportion of degrees earned in those broad fields in 1982[2] in Table 26. The data indicate that the job market was considerably better for technical graduates, relative to their proportion of all graduates, than was true for the social science and humanities graduates.

As has been pointed out in several studies by the Bureau of Labor Statistics,[28] the economy has been unable to absorb all college graduates in jobs typically requiring a college degree since the early seventies. Both engineering graduates and those in science and mathematics obviously have had more success finding employment related to their fields than have those in the humanities and some of the social sciences.

TABLE 25

AVERAGE ANNUAL SALARY OFFERS TO BACHELOR'S DEGREE CANDIDATES, 1984

FIELD	TOTAL	MEN	WOMEN
Accounting	$19,524	$19,560	$19,488
Business/Management	18,660	18,792	18,444
Marketing	17,820	18,288	17,220
Humanities	17,724	18,768	17,016
Economics	19,980	20,148	19,716
Other Social Sciences	17,424	18,780	16,224
Engineering	26,276	26,252	26,430
Aeronautical	25,836	25,896	25,380
Chemical	27,420	27,312	27,624
Civil/Constr/San/Transp	22,764	22,800	22,524
Electrical/Computer	26,556	26,556	26,604
Geological	24,492	24,324	26,580
Industrial	25,224	25,152	25,356
Mechanical	26,280	26,256	26,460
Metallurgical/Ceramic	26,556	26,400	26,904
Mining	24,876	24,816	27,600
Nuclear & Eng Physics	26,388	26,352	26,544
Petroleum	29,568	29,652	28,680
Engineering Technology	24,936	25,020	23,580
Agricultural Sciences	17,016	16,992	17,076
Biological Sciences	16,824	18,168	15,384
Chemistry	21,072	21,240	20,796
Computer Sciences	24,552	24,828	24,060
Health Professions	18,912	21,084	18,660
Mathematics	23,400	23,760	22,992
Other Physical/Earth Sciences	22,800	23,148	20,832

SOURCE: College Placement Council, **Salary Survey**, Formal Report No. 3, July, 1984

TABLE 26
DISTRIBUTION OF COLLEGE GRADUATES, NON-TEACHING JOB OFFERS AND HIRES, BY CURRICULUM GROUP

FIELD	BACHELOR'S			MASTER'S		
	Degrees[5] 1981-82	Hires[6] 1983-84	Offers[7] 1983-84	Degrees[5] 1981-82	Hires[6] 1983-84	Offers[7] 1983-84
Engineering[1]	9.4%	36.7%	51.8%	8.9%	26.7%	30.3%
Science/Math/Other Tech.[2]	21.4	17.4	13.1	18.0	17.1	12.0
Business[3]	25.3	39.7	29 ?	30.3	53.2	55.4
Social Sci./Humanities[4]	43.9	6.3	5.9	42.8	3.0	2.3

[1]
[2]Includes engineering technologies
[3]Includes computer sciences and health (medical) professions
[4]Includes accounting, marketing, business management, finance, etc.
[5]Includes liberal arts, humanities, social sciences, and other non-technical fields
[6]Exclusive of degrees in education
[6]Actual hires by 399 employers in business, industry, government, and non-profit and educational institutions, except for teaching positions
[7]To inexperienced graduates, reported by 187 placement offices at 162 colleges and universities

SOURCES: College Placement Council and National Center for Education Statistics

Even at the doctoral level, this continues to be true. Among the 1983 Ph.D. graduates, 24.3% of those in physical science, math and engineering were still seeking employment or a postdoctoral position when the degree was awarded, compared with 29.5% of the graduates in social and behavioral sciences and 33.2% of the humanities graduates.[6]

Demand for Experienced S/E Professionals

Employment of experienced scientists and engineers as well as other professionals is measured by the Bureau of Labor Statistics in its monthly surveys of about 40,000 households, but the figures are aggregated into the category of "professional and technical workers" which includes many persons who are not scientists and engineers. Engineering employment and unemployment is calculated quarterly from this BLS survey. The unemployment rate in engineering, reported on an annualized basis by BLS, reached 1.9% in 1982, after five previous years of 1.2 to 1.4% unemployment rates.[29] The unemployment rate for the "professional and technical workers" category was 3.2% in 1982, only slightly above the rates of the previous few years. Typically, the unemployment rate for engineers averages about half the unemployment rate for all professional and technical workers.

Another comparative index of demand for scientists and engineers is the High Technology Recruitment Index maintained by Deutsch, Shea and Evans.[30] This index measures classified advertising for scientists and engineers in newspaper display ads, newspaper classified ads and technological journals. The index, maintained monthly since 1961, rose sharply in 1976 and 1977, and remained high through 1981 (fig. 18). The drop in 1982 and 1983 coincided with the decrease in the recruitment of new graduates, and the rise in the Index through May of 1984 also reflects the pattern for new graduates. However, the Index started down again in June, dropping through the remainder of the year. On an annual basis, the Index averaged 133 in 1984, well above the base year norm of 100 and the 1983 annual average of 101.

Academic Demand

The number of scientists and engineers employed full time at colleges and universities increased 26% from 1975 to 1984, rising from a total of 223,336 in January 1975 to 281,561 in January 1984, according to surveys by the National Science Foundation[31] (Table 27). Some employment fields grew much faster than others, with computer scientists increasing 20.5% per year over those nine years compared with an increase of only 0.3% per year for chemists. The proportion of women among academically employed scientists and engineers increased at

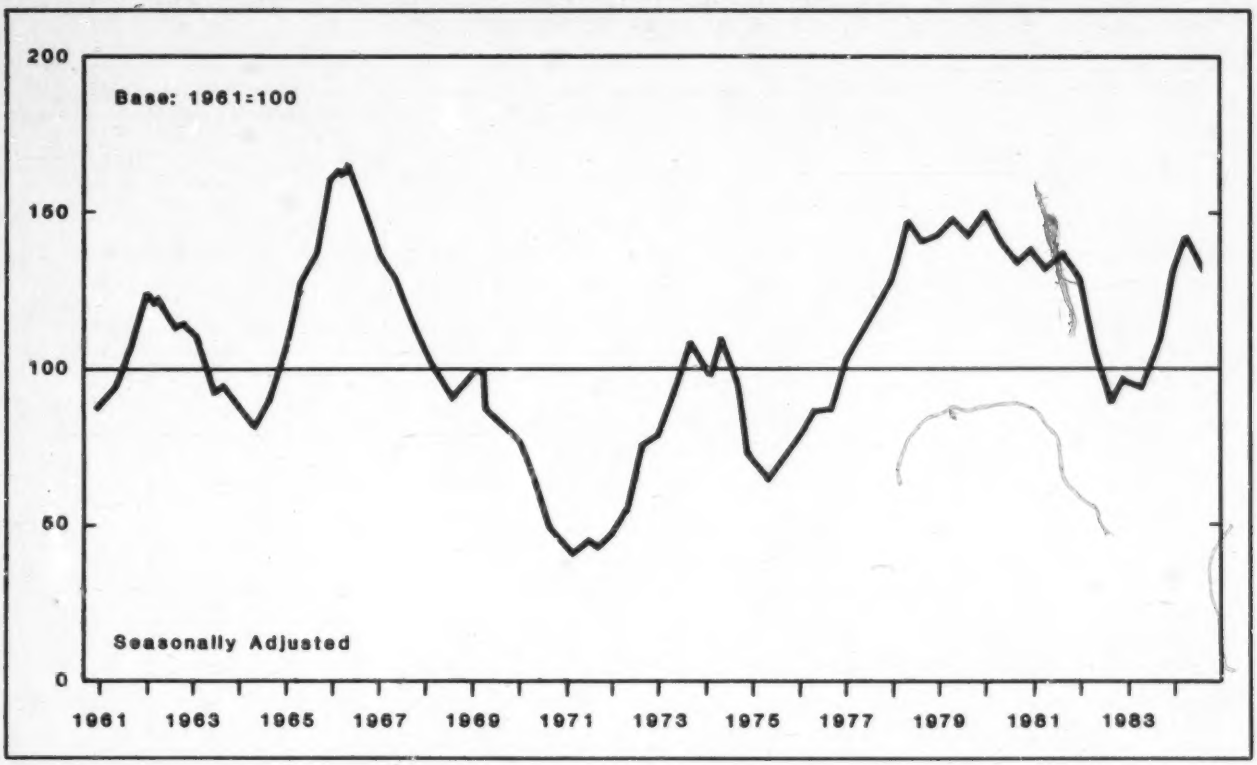

Figure 18. Deutsch, Shea & Evans High Technology Recruitment Index
[Source: Deutsch, Shea & Evans]

least slightly in almost all fields, but rose only five percentage points in nine years as a proportion of total science and engineering employment.

Total academic employment in science and engineering should hold steady or decline slightly through the rest of the decade as the size of the college-age population drops. However, any significant increases in federal budgets for research would tend to maintain a stable size in academic employment, although the emphasis of such research might significantly alter the present proportions in each major field group. These proportions have been changing slowly with above-average increases for engineers, computer scientists and life scientists and below-average increases for physical scientists, social scientists and psychologists.

The lack of substantial growth in science and engineering faculty has resulted in a highly tenured faculty in these fields, with little room for input of new doctorates. The proportion of recent doctorates - those holding their Ph.D.s for seven years or less - on the full-time faculty of science and engineering departments in Ph.D.-granting institutions dropped from 39% in 1968 to 28% in 1974 and to 21% in 1980.[32] The percentage of faculty with tenure rose from 70% in 1974 to 74% in 1980, ranging from 59% in computer science to 83% in physics.

Among 188,900 doctorate faculty members in science and engineering in 1983, 61.7% are tenured and 10% are neither tenured nor in a tenure track. Only 12% are 35 or younger.[4] However, faculty members in the life sciences include a higher proportion below age 36 (20.6%), a higher proportion who are not in a tenure track (13.1%) and a lower proportion of tenured faculty (56.6%) than is true for the engineering, math and physical science (EMP) group or the behavioral and social science group. As shown in Table 28, women faculty are generally younger than men, but are considerably less likely than men to hold tenure, regardless of field or age group; and more likely to be outside the tenure track. The expected drop in college enrollments over the next several years indicates that a further decline in the proportion of recent doctorates can be expected, and that both men and women will have difficulty finding tenure track faculty slots available.

TABLE 27

FULL-TIME SCIENTISTS AND ENGINEERS EMPLOYED IN COLLEGES AND UNIVERSITIES, JANUARY 1975, 1980, 1984

FIELD	1975		1980		1984		1975-84
	Total	Percent Women	Total	Percent Women	Total	Percent Women	Avg. Ann. % Increase Total
TOTAL	**223,336**	**15.0**	**255,659**	**17.3**	**281,561**	**20.3**	**2.9**
ENGINEERS	**22,580**	**1.6**	**26,525**	**2.7**	**29,435**	**3.8**	**3.4**
Aeronautical/Astronautical	944	2.6	1,144	2.4	1,138	2.0	2.4
Chemical	1,603	1.6	1,893	3.1	2,043	5.5	3.1
Civil	3,832	1.6	4,332	2.7	4,884	4.3	3.1
Electrical	5,393	1.1	6,398	1.8	7,303	2.7	3.9
Mechanical	4,355	.7	4,809	1.9	5,411	1.8	2.7
PHYSICAL SCIENTISTS	**26,662**	**7.5**	**28,101**	**8.9**	**29,030**	**9.9**	**1.0**
Chemists	13,823	10.3	14,392	12.4	14,155	7.3	.3
Physicists	10,940	3.5	11,417	4.4	11,531	5.0	.6
ENVIRONM'TL SCIENTISTS	**6,787**	**4.7**	**8,315**	**7.9**	**8,933**	**9.4**	**3.5**
Earth Scientists	5,172	4.3	5,566	7.2	5,713	7.9	1.2
Atmospheric Scientists	559	6.1	786	5.5	805	6.7	4.9
Oceanographers	1,056	5.9	1,387	9.0	1,538	15.7	5.1
MATHEMATICIANS	**18,699**	**13.2**	**19,916**	**16.0**	**21,407**	**18.2**	**1.6**
COMPUTER SCIENTISTS	**3,705**	**12.0**	**6,131**	**14.8**	**10,533**	**19.7**	**20.5**
LIFE SCIENTISTS	**90,684**	**19.9**	**108,619**	**22.3**	**122,689**	**27.7**	**3.9**
Agricultural	13,235	11.7	14,429	9.2	15,572	11.6	2.0
Biological	33,462	18.9	38,840	21.2	41,399	23.8	2.6
Medical	43,987	23.1	59,783	23.4	54,506	25.8	2.7
PSYCHOLOGISTS	**15,973**	**22.4**	**16,756**	**25.8**	**17,087**	**26.3**	**.8**
SOCIAL SCIENTISTS	**33,246**	**16.7**	**41,296**	**19.0**	**42,447**	**19.1**	**1.2**
Economists	10,169	8.5	11,118	10.0	12,122	10.9	2.1
Sociologists	10,744	24.6	10,859	27.1	10,208	26.6	.6
Political Scientists	8,687	10.3	8,840	12.7	9,139	13.6	.6

Source: National Science Foundation

Engineering Faculty

There is a shortage of faculty in engineering and in computer science. In fall 1983, the faculty vacancy rate in engineering was 8.5 percent with the situation having improved slightly in private schools but worsened in public institutions since fall 1982, when 7.9% of the authorized, full-time engineering faculty positions in engineering schools were unfilled - down from 9% reported in 1981.[33] There are now an estimated 18,440 authorized faculty positions in U.S. engineering schools, with an estimated 1,570 vacancies. Of the unfilled positions in fall 1982, 56.6% were reported vacant in 1981, about the same percentage of year-long vacancies reported in the previous year. Unfilled positions as a percentage of authorized full-time positions are shown by field of engineering in Table 29. , The problem is particularly severe in computer engineering and electrical engineering, and has remained essentially unchanged from 1980 to 1983.

The 1982 survey found that 18% of all full-time engineering faculty members did not receive their B.S. degrees from an institution in the U.S., and over 13% received their Ph.D. from the institution at which they are now employed. The highest percentage of foreign born faculty is in computer science/engineering - 20.7%. More than one fourth (26%) of all assistant professors in engineering did not receive B.S. degrees from a U.S. university.[33] The problem of insufficient faculty (which is experienced in the computer sciences as well)[13] may result in a significant reduction in the

TABLE 28

TENURE STATUS OF ACADEMICALLY EMPLOYED SCIENCE AND ENGINEERING Ph.D.'s BY FIELD OF DOCTORATE, AGE, AND SEX, 1983

Age and Tenure Status	FIELD OF DOCTORATE/SEX							
	ALL FIELDS		EMP		LIFE SCIENCES		BEHAV/SOC SCI	
	Men	Women	Men	Women	Men	Women	Men	Women
Totally Academically Employed (N)	161,400	27,500	65,200	3,900	47,800	10,900	48,400	12,700
	PERCENT							
Tenured	65.5	39.2	64.8	28.9	62.2	32.1	69.6	45.4
Not Tenured	25.8	47.1	24.6	45.7	29.2	51.4	24.2	43.9
In Track Position	14.0	20.9	12.5	20.2	15.6	17.6	14.2	24.0
Not In Track Position	8.4	19.9	8.2	20.4	10.0	26.6	7.0	14.0
Type Position Unknown	3.5	6.3	3.9	5.1	3.4	7.2	3.0	5.9
No Report	8.7	13.7	10.5	15.4	8.6	16.5	6.2	10.7
Age - 35 or Under (N)	26,400	7,600	9,900	1,100	8,900	3,200	7,600	3,300
	PERCENT							
Tenured	13.4	7.6	13.5	7.3	6.4	3.4	21.3	11.7
Not Tenured	66.0	69.5	64.8	66.6	69.7	66.7	63.1	73.0
In Track Position	44.0	36.8	43.9	40.7	42.6	25.5	45.8	46.4
Not In Track Position	15.4	25.1	14.4	21.6	20.8	32.1	10.5	19.4
Type Position Unknown	6.5	7.5	6.5	4.3	6.3	9.1	6.8	7.2
No Report	20.7	23.0	21.7	26.1	23.9	29.9	15.6	15.3
Age - 36 to 45 (N)	63,400	11,700	25,900	1,600	18,700	4,600	18,800	5,500
	PERCENT							
Tenured	63.9	41.8	64.1	40.6	60.0	33.7	67.6	49.0
Not Tenured	28.9	46.7	26.7	45.6	33.5	53.1	27.5	41.7
In Track Position	15.6	20.4	13.0	18.4	18.7	19.3	16.2	21.9
Not In Track Position	9.8	19.8	9.6	22.1	10.9	26.3	8.8	13.5
Type Position Unknown	3.6	6.6	4.1	5.1	3.9	7.5	2.5	6.3
No Report	7.1	11.5	9.2	13.8	6.5	13.2	4.9	9.3
Age - 46 or Older (N)	71,500	8,200	29,400	1,200	20,200	3,000	21,900	3,900
	PERCENT							
Tenured	86.2	64.9	82.7	65.0	88.8	60.0	88.4	68.8
Not Tenured	8.2	27.0	9.3	27.1	7.3	32.8	7.6	22.5
In Track Position	1.5	7.0	1.6	4.2	1.4	6.8	1.3	8.0
Not In Track Position	4.5	15.3	4.9	17.0	4.3	21.2	4.2	10.3
Type Position Unknown	2.2	4.6	2.8	5.9	1.6	4.8	2.1	4.2
No Report	5.6	8.1	8.0	7.9	3.9	7.2	4.0	8.8

NOTE: EMP = Engineering, Mathematics, Computer Sciences, Physics/Astonomy, Chemistry and Earth/Environmental Sciences.
Life Sciences = Agricultural Sciences, Medical Sciences, and Biological Sciences.
Behavorial/Social Sciences = Psychology and Social Sciences.

SOURCE: National Research Council

number of bachelor's degree awards projected over the remainder of this decade, and perhaps into the next.

The faculty shortage has developed because industry has recruited most of the graduates at the bachelor's level, leaving rela-

TABLE 29

UNFILLED POSITIONS AS PERCENTAGE OF AUTHORIZED FULL-TIME ENGINEERING FACULTY POSITIONS, FALL 1981-83

FIELD	ALL SCHOOLS		
	1981	1982	1983
Aero & Astro	5.1%	5.8%	7.7%
Chemical	8.8	6.0	7.1
Civil	8.2	6.0	5.2
Comp. Sci./Engrg.	17.0	16.8	15.6
Electrical	8.5	7.7	9.6
Industrial	11.6	9.1	10.4
Mechanical	8.9	7.8	7.6
All Other	8.8	7.4	8.0
ALL FIELDS	9.0	7.9	8.5

SOURCE: Engineering College Faculty Shortage Project - American Society for Engineering Education

tively few to go on to graduate school and prepare for teaching. Additionally, some engineers already on university faculties have been lured away by higher salaries and better equipment for research in industry, and by increased teaching loads and fewer graduate assistants in academe. This is a two way street, however. In 1982, 1.8% of full-time engineering faculty left their institutions to accept employment in industry or government. However, about the same number left industry jobs to join academic faculties. In 1983, academic institutions received a net gain of 171 from these transfers.[33]

Although a number of steps have been taken over the past few years to address the engineering faculty problem, they may be both too little and too late to avoid a negative effect on both the quantity and quality of graduates in this decade. There is already some evidence that faculty shortages in engineering are impacting educational quality as student to faculty ratios have increased and the number of engineering programs that have been awarded full six-year accreditation has dropped. The number of engineering programs that are not accredited by the Accreditation Board for Engineering and Technology (ABET) almost doubled between 1978 and 1983.[34] Although faculty salaries have improved significantly, this improvement has not been sufficient to attract more U.S. graduates to teaching careers. Faculty shortages continue to be more severe at public institutions than private ones, partially because salaries are higher at the private schools. Private schools also report more difficulty in recruiting and retaining faculty than do public schools (Table 30). But whether it is salary levels or other factors that make academic careers less inviting, only 55 percent of new engineering doctorates entering the U.S. labor force in 1983 indicated plans for academic employment, compared with 70 percent in 1969 and 63.6 percent in 1980 who had such plans.[6]

Full time undergraduate enrollments in engineering have more than doubled during the past decade, from 201,094 to 406,144. Graduate enrollment almost doubled from 32,637 to 57,366. However, the number of full-time engineering faculty increased only 14 percent from 16,859 to 19,226 while the total number of faculty rose only 20 percent from 22,309 to 26,700.

The evident pressures on engineering faculty time are aggravated by increased demand for sponsored research, whose volume rose from $469 million to $1.69 billion over the decade, or 50 percent in constant dollars (fig. 19).[35] Academic research facilities and equipment have not been kept up to date, and antiquated facilities are causing loss of research dollars.

TABLE 30

CHANGE IN ABILITY TO RECRUIT AND RETAIN FACULTY, FALL 1983

Degree of Change	Percent Public School		Percent Private School		Percent All Schools	
	1983	1982	1983	1982	1983	1982
Substantial Increase	3.4	3.0	1.8	10.3	2.8	5.7
Slight/Moderate Increase	32.8	22.2	33.3	34.5	33.0	26.8
No Change	34.4	15.2	43.8	13.8	37.5	14.7
Slight/Moderate Decrease	29.4	28.3	21.1	25.9	26.7	27.4
Substantial Decrease	0.0	31.3	0.0	15.5	0.0	25.4

SOURCE: **Engineering Education** October 1984, p.52.

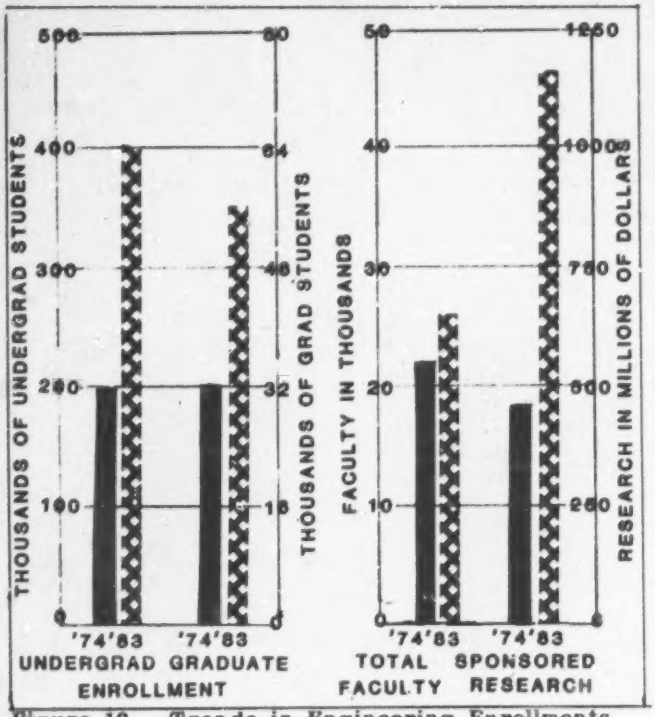

Figure 19. Trends in Engineering Enrollments, Faculty and Sponsored Research
[Data Sources: Engineering Manpower Commission, American Society for Engineering Education]

Computer Science Faculty

Similar problems exist in computer science departments. The total number of Ph.D. graduates, the next generation of researchers and teachers, has averaged only 221 per year for the past decade, with many of the graduates (one fourth in 1983) being foreign citizens on temporary visas. Only 55.6% of that class indicated plans for employment in educational institutions.[6]

Undergraduate enrollments doubled between 1975 and 1980, and probably doubled again by 1984. Bachelor's degrees in computer sciences increased 749 percent from 2,388 to 20,267 from 1971 to 1982, almost doubling between 1980 and 1982, and the demand for computer science courses from students majoring in other fields adds further teaching load. Many students are attracted to computer science by its excellent career opportunities, and additional numbers of students are being encouraged by the computer revolution to take introductory and intermediate programming courses in order to be familiar with the computer as a tool in other disciplines. This has resulted in ballooning class sizes, inadequate terminal and computing facilities, insufficient laboratory facilities and an overloaded faculty. In many cases, the heavy teaching loads have halted faculty research, causing discontent among those who want to or must do research to achieve tenure and promotions.

These shortages have put great pressure on salaries. In 1984, average starting salaries outside the academic sector were $24,550 at the B.S. level and $30,060 at the M.S. level.[14] A year earlier, new Ph.D.s in industry averaged $38,255.[36] By comparison, the median salary for new assistant professors in computer science in 1983-84 was $25,549 in private and $23,161 in public institutions.[37] As in engineering, there is clearly little incentive for B.S. holders to contemplate graduate school when their current offers are comparable to those paid the newest faculty recruits (Table 31).

There is no excess of mathematics Ph.D.s to be converted to computer science faculty. There was virtually full employment in 1983 of Ph.D. recipients in mathematics from the 1982 class, according to the annual survey by the American Mathematical Society.[38] Further, since the number of doctoral awards in mathematics has continued to drop steadily since 1970, there has been no excess supply from previous years. Additionally, there are virtually no unemployed ex-faculty members who have left academic life.

In 1982-83, about 19,615 full-time mathematical sciences faculty members were employed in U.S. colleges and universities, including 15,125 doctorate holders. This is an increase

TABLE 31

AVERAGE MONTHLY STARTING SALARY OFFERS, SELECTED FIELDS, 1984

FIELD	Degree Level		
	Bachelor's	Master's*	Ph.D.'s
Engineering			
Chemical	$2,285	$2,557	$3,239
Civil	1,895	2,227	3,108
Electrical	2,213	2,584	3,430
Mechanical	2,190	2,524	3,199
Mathematics	1,950	2,397	2,963°
Computer Science	2,046	2,505	
Chemistry	1,756	2,228	2,960
Oth Phys/Earth Sci.	1,900	2,440	
Humanities	1,477	1,561	
Social Sciences	1,537	1,648	
Business	1,555	2,279	

*Inexperienced
°Includes Operations Research, Statistics, etc.

SOURCE: College Placement Council

of about 700 from the previous year total, including a 462 increase in doctorate holders. This one year growth represents the largest increase in a decade. Course enrollments rose by four percent, and class sizes were nearly stable. This net change of about 700 faculty members included 2,290 new hires and 1,585 faculty members leaving. Among new hires, only 179 were from nonacademic employment, but faculty leaving included 257 moving into nonacademic positions.[38] Thus, it seems apparent that industry draws out more faculty members from this field than it supplies faculty candidates, at least for now. The number of non-doctorate faculty members in U.S. colleges and universities showed no significant change between 1983 and 1984.

An increasing source for new faculty hires in mathematics, as in engineering and computer science, is other countries. Among new doctoral faculty hired in 1982-83, 5.5% were from outside the U.S.[38] The proportion of Ph.D.s in the mathematical sciences earned by foreign citizens on temporary visas has risen from 10.9% in 1970 to 29.8% in 1983. In the computer sciences, the proportion rose from 21.5% in 1978 to 25.3% in 1983. Only 285 Ph.D.s were awarded in computer science in 1983, and 72 of these - more than one fourth - were awarded to noncitizens on temporary visas. Only 45 percent planned academic employment.[6]

Despite the tremendous growth in computer-related degree programs since 1977, the number of graduates from four year programs numbers about half the estimated annual need; the number of master's degrees awarded were about one sixth of those needed and the production of doctorates was still at only one fifth of those needed (Table 32).[13] This shortage is expected to continue, since even with lower overall enrollments, the enrollments in computer science courses can be expected to increase.

TABLE 32

ESTIMATES OF ANNUAL COMPUTER MANPOWER NEEDS VERSUS ESTIMATES OF PRODUCTION FOR 1982-1983

	LEVEL OF EDUCATION			
	Post-Sec. Voc. & 2-Yr.	B.S.	M.S.	Ph.D.
Annual Needs	26,376	54,351	34,153	1,309
Estimated 1982-1983 Production	27,085	28,203	5,961	254
Production/Need	1:1	1:2	1:6	1:5

SOURCE: Computer Manpower-Supply and Demand-By States, Fifth Edition, 1984.

High School Science and Math Teachers

The teacher problem dips below the college level. In 1984, an annual survey of teacher placement officers continued to show considerable shortage of qualified teachers for mathematics, physics, and chemistry, as has been true since the first survey in 1979. For the first time in the 1984 survey, placement officers were asked to indicate shortages of teachers in computer programming, and found a considerable shortage (4.34 on a scale of 1 to 5) in this teaching area as well, with all of these shortage areas continuing in the 1985 survey (Table 33).[39] The fact that the United States is dependent on secondary school teachers to attract young people into scientific and technological careers compounds the problem of faculty shortage.

TABLE 33

RELATIVE TEACHER DEMAND BY TEACHING AREA AND YEAR

	1978	1979	1980	1981	1982	1983	1984
Mathematics	3.86	4.68	4.80	4.79	4.81	4.75	4.78
Physics	4.04	4.36	4.28	4.56	4.41	4.46	4.45
Chemistry	3.72	4.09	4.18	4.42	4.13	4.30	4.25
Computer Prog.							4.34
Data Processing					3.86	4.36	4.18
Earth Science	3.44	3.82	3.64	4.08	3.89	3.80	3.70
General Science							3.65
Biology	2.97	3.49	3.50	3.98	3.66	4.10	3.40

NOTE: Scale 1 to 5: 1=Surplus, 3=Balance, 5=Considerable Shortage.

SOURCE: James M. Akin

Demand in Research and Development

The National Science Foundation reports that in 1982, 969,600 scientists and engineers were working primarily in research and development, with another 253,600 working in management or administration of R & D. The largest group, 697,000, were in business and industry, with 102,300 in academic institutions, 98,000 employed by the federal government, 32,200 by state and local governments, 28,700 in non-profit organizations and the remainder scattered in other employment sectors. More engineers (617,500) than scientists (352,000) are employed in R & D, with scientists dominant in both basic and applied research, and engineers in development.[19]

Science and engineering employment in research and development is, of course, tied directly to R & D funding, which was expected to reach $97 billion in 1984, an increase of 11% over 1983 (Table 34). For the past five years, industry has been both the leading supporter and the largest performer of R & D.

The National Science Foundation anticipates 7% real growth in 1985 national R & D expenditures, with defense and the state of the

economy being the major factors accounting for that growth.[40] Funds for R & D by performer and source are shown in Table 34.

The President's proposed Budget for Fiscal Year 1986 includes a 13% increase in funding (10% in real dollars), with defense eating up all of the increase as it consumes 66% of the total. R & D for health and human services makes up 10%, energy 9%, NASA 7%, the National Science Foundation 3% and all other activities 5%.[41]

The number of scientists and engineers engaged in R & D in industry increased 50% from 1973 to 1983, while the cost per industrial scientist or engineer rose 90% over that period, as shown in Table 35.[42]

Another estimate of R & D expenditures in the U.S. is the annual forecast by Battelle Columbus Laboratories, which estimates that expenditures will surpass $107 billion in 1985, a real increase of about 4% after assuming a 6.5% inflation rate. Again, industrial R & D funding will increase more than federal funding, and will account for 51.3% of total R&D funding.[43] In dollar terms, industrial R & D spending is estimated at $55 billion, up 11.4% over 1984; federal support is estimated at $48.7 billion (45.4% of the total), representing an increase of 10%, while academic R & D spending is predicted to be $2.28 billion (2.1% of the total); and other non-profit organizations will allocate slightly more than $1.3 billion or 1.2% of the total.

TABLE 34

FUNDS FOR RESEARCH AND DEVELOPMENT
(Dollars in Millions)

Year	Total	Federal Government	Industry†	Academic Sector		Other nonprofit institutions†
				Universities & Colleges	Associated FFRDC's§	
			By Performer			
1975	$ 35,213	$ 5,354	$24,187	$3,409	$ 987	$1,276
1976	39,018	5,769	26,997	3,729	1,147	1,376
1977	42,783	6,012	29,825	4,067	1,384	1,495
1978	48,129	6,811	33,304	4,625	1,717	1,672
1979	54,933	7,417	38,226	5,361	1,935	1,994
1980	62,618	7,632	44,505	6,060	2,246	2,175
1981	71,864	8,425	51,810	6,818	2,486	2,325
1982	79,233	9,141	57,927	7,261	2,479	2,425
1983	86,559	10,582	62,920	7,745	2,737	2,575
1984 (est.)	97,200	12,300	70,500	8,700	2,900	2,800
1985 (est.)	109,200	13,400	80,000	9,600	3,100	3,100
			By Source			
1975	35,213	18,109	15,820	749		535
1976	39,018	19,914	17,694	810		600
1977	42,783	21,594	19,629	888		672
1978	48,129	23,876	22,450	1,037		766
1979	54,933	26,815	26,081	1,200		837
1980	62,618	29,451	30,911	1,323		933
1981	71,864	33,402	35,941	1,523		998
1982	79,233	36,472	40,025	1,683		1,053
1983	86,559	40,390	43,154	1,830		1,185
1984 (est.)	97,200	45,700	48,100	2,100		1,300
1985 (est.)	109,200	51,500	54,000	2,300		1,400

† Includes expenditures for FFRDC's administered by this sector. They account for less than 5 percent and 15 percent, respectively, of the industry and nonprofit performance totals.
§ Federally Funded Research and Development Centers (FFRDC's) administered by individual universities and colleges and by university consortia.

SOURCE: National Science Foundation.

TABLE 35

NUMBER AND COST/PERSON OF R&D SCIENTISTS AND ENGINEERS IN INDUSTRY

Year	Total R&D Indus. Scientists & Engs.	Cost/Industrial R&D Scientist & Engineer
1973	357,700	59,200
1974	360,000	63,300
1975	363,300	66,500
1976	364,400	72,200
1977	382,800	75,800
1978	404,400	80,400
1979	423,900	87,400
1980	450,600	94,900
1981	487,800	103,900
1982	509,800	112,800
1983	535,600	

SOURCE: National Science Foundation.

Regardless of source of funds, industry will continue to perform most of the work, with 75% of the total. Of the rest, in-house government R & D will account for 11%, academic institutions about 12% and other non-profit organizations about 3%.

The size of uture R&D budgets, the cost per R & D scientist and engineer, and the relative share of R & D funds devoted to particular kinds of activity all will influence both the amount of R & D employment, and the kinds of scientists and engineers employed in R & D over the remainder of the decade.

PROJECTIONS OF SUPPLY AND DEMAND

Estimates of long range future demand usually are either projections based on past trends which incorporate certain demographic statistics, or surveys based on the hiring plans of major employers. The more sophisticated models factor in expected changes in economic conditions, budget emphasis, and social conditions. The accuracy of the forecast is, of course, dependent on the accuracy of the assumptions made in regard to the change or stability of conditions that affect demand. For this reason, many forecasters utilize more than one "scenario" to describe the expected range of changes.

The National Science Foundation has provided an examination of supply and demand in science and engineering that compares 1982 with 1987.[20] The demand side utilizes four different scenarios to describe the two factors which were assumed to be major determinants of scientific, engineering and technical (SET) employment, based on their ability to affect the level and pattern of industrial activity - namely the general performance of the U.S. economy and the level and distribution of defense expenditures. The four scenarios variously assume high or low defense expenditures, in comparison with 1982, and high or low economic conditions. The forecast for demand utilizing the high defense and high economic growth scenario is shown in Table 36.

Forecasts of supply usually incorporate assumptions about expected new entrants to a field based on anticipated degree awards; plus an addition for immigrants and a subtraction from current supply for deaths, retirements and emigrants. The NSF model utilized to provide the supply forecasts shown in Table 36 includes a unique feature to estimate supply response elicited by changing job opportunities. This feature is especially useful in the face of rapid, short-term growth requirements such as are anticipated under the defense buildup, because it reflects both the anticipated response of students to major in fields showing increasing job opportunities, and also the response of more experienced personnel to remain in or transfer into these jobs from other occupations. The occupational mobility of the experienced S/E work force provides particular flexibility to the S/E labor market.

The relative balance between expected supply and expected employment based on this scenario indicates a potential shortage of supply only in aeronautical/astronautical engineering, industrial engineering, and computer specialties by 1987. On the other hand, the "surplus" supply ranges from only one percent overall in engineering to 8.6% in science. Individual fields showing a significant oversupply include agricultural sciences, biology, and social sciences, particularly sociology. These also are the fields with large oversupply as a percent of total supply in 1983. However, the slight undersupply of electrical/electronic engineers in 1983 has disappeared in this model by 1987.

The source of anticipated growth in employment is of particular interest in these projections, since any significant change in either of the two major factors - general economic growth or defense expenditures - would change the forecasts in different fields in quite different ways. In the same high economic growth, high defense expenditure scenario as is shown in Table 36, the annual rate of growth projected between 1982 and 1987 that is related to defense requirements is significantly higher than the growth rate for non-defense requirements, as shown in Table 37. Actual growth, however, is considerably higher in the non-defense sector, particularly for scientists. In

TABLE 36

SUPPLY/DEMAND BALANCE OF SCIENTISTS AND ENGINEERS BASED ON A NET-MOBILITY SUPPLY MODEL, 1983 AND 1987

OCCUPATION	1983				1987			
	TOTAL SUPPLY	NEW ENTRANTS	DEMAND	BALANCE AS PERCENT OF SUPPLY	TOTAL SUPPLY	NEW ENTRANTS	DEMAND	BALANCE AS PERCENT OF SUPPLY
				(In thousands)				
Total Scientists	**566.2**	**87.0**	**523.0**	**7.7**	**639.9**	**92.2**	**584.7**	**8.6**
Agricultural Scientists	20.8	5.3	17.6	15.4	22.2	5.0	18.4	17.1
Biologists	67.6	19.2	56.7	16.1	76.3	19.7	62.5	18.1
Chemists	95.5	6.1	93.9	1.7	104.6	6.4	102.8	1.7
Geologists	45.7	4.4	42.5	7.0	51.6	4.9	47.9	7.2
Mathematical Scientists	55.3	5.8	53.0	4.2	63.0	5.9	60.6	3.8
Physicists	23.6	2.9	21.7	8.1	26.6	3.1	24.2	9.0
Other Life & Physical Scientists	30.1	1.9	28.6	5.0	33.3	2.0	31.3	6.0
Social Scientists	227.6	41.4	209.0	8.2	262.3	45.2	237.0	9.6
Economists	34.7	7.5	31.4	9.5	40.7	8.2	36.2	11.1
Psychologists	98.4	12.9	92.7	5.8	113.6	14.3	106.2	6.5
Sociologists	12.5	6.1	9.6	23.2	25.2	7.3	10.7	29.6
Social, n.e.c.	82.0	14.9	75.3	8.2	92.8	15.4	83.9	9.6
Total Engineers	**1,217.2**	**64.0**	**1,207.6**	**0.8**	**1,437.3**	**66.8**	**1,423.1**	**1.0**
Aero/Astronautical	70.0	1.9	72.4	-3.4	104.8	2.2	109.2	-4.2
Chemical	58.0	5.5	55.4	4.5	64.2	5.4	60.9	5.1
Civil	171.6	10.2	171.5	0.1	190.1	10.2	188.9	0.6
Electrical/Electronic	347.9	14.0	348.9	-0.3	421.3	15.6	420.6	0.2
Industrial	114.2	4.0	114.9	-0.6	129.8	4.1	130.8	-0.8
Mechanical	217.9	11.4	214.3	1.7	253.4	11.7	248.2	2.1
Metallurgical	16.3	1.4	15.8	3.1	19.2	1.4	18.5	3.6
Mining/Petroleum	28.5	2.1	27.6	3.2	32.5	2.3	31.6	2.8
Engineers, n.e.c.	192.8	13.5	186.8	3.1	222.0	13.9	214.4	3.4
Computer Specialists*	**477.7**	**10.8**	**486.9**	**-1.9**	**592.8**	**13.5**	**603.8**	**-1.9**

* Includes both computer systems analysts and computer programmers

Note: This projection is based on the high-economic growth and high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

Source: National Science Foundation

1982, 3.0% of the requirements for scientists are in defense; and in 1987, this proportion increases only to 3.9%. In engineering, however, the defense requirements are 12.2% of all requirements in 1982, rising to 15.9% in 1987. Similarly, technician requirements for defense are 5.7% of all requirements in 1982, rising to 7.0% in 1987.

Of course, within these broad groupings the contrast in specific fields is far greater. Unlike most fields, defense requirements for aeronautical/astronautical engineers constitute more than half of total requirements in both years. Conversely, most chemists are engaged outside of defense in both years. Thus it is apparent that a significant lowering of defense budgets would have little effect on total demand in some fields, but tremendous effect in others. On the other hand, a slow or negative economic growth would affect requirements in all fields, although the total effect, if coupled with continuing high defense expenditures, would affect some fields far less than others.

Other projections of demand also are available. The American Electronics Association (AEA) examines projected labor-market balance in engineering and computer specialty occupations in 1987,[34] and projects demand at about the same level as does NSF. However, although supply projections for the number of new entrants are similar in both studies, the NSF study concludes that the remaining need in electrical engineering will be filled by occupational mobility from other related fields, while AEA sees a shortfall of about one third of new jobs for electrical/electronic (EE) engineers that cannot be filled by new graduates. AEA believes that in spite of the availability of

people from other fields, without more EE/CE and computer science graduates, the electronics industry will continue to be hampered by supply/demand imbalances.

The Bureau of Labor Statistics (BLS) regularly forecasts employment trends ten or more years ahead, using economic trend models hedged by consideration of the expected federal R & D budgets, defense expenditures, and industrial expansion to meet demand for more goods and services. Current estimates are provided in three scenarios for 1995, representing projected employment referenced to actual employment in 1982.[28] These projections move from the base year to the pro-

TABLE 37

PROJECTED GROWTH IN DEFENSE AND NONDEFENSE REQUIREMENTS OF SCIENTISTS, ENGINEERS, AND TECHNICIANS: 1982-87--OPTIM/HIGH
(in thousands)

	TOTAL REQUIREMENTS			DEFENSE REQUIREMENTS			NONDEFENSE REQUIREMENTS		
OCCUPATION	1982	1987	Annual growth rate-%	1982	1987	Annual growth rate-%	1982	1987	Annual growth rate-%
TOTAL SCIENTISTS	**727.4**	**888.0**	**4.1**	**22.0**	**34.2**	**9.2**	**705.5**	**854.2**	**3.9**
Computer Systems Analysts	219.3	303.3	6.7	10.0	17.9	12.3	209.2	285.5	6.4
Life:									
Agricultural	17.2	18.4	1.4	0.1	0.2	14.9	17.1	18.2	1.2
Biologists	55.4	62.5	2.4	0.7	0.8	2.7	54.7	61.7	2.4
Physical:									
Chemists	90.9	102.8	2.5	2.9	3.8	5.5	88.0	99.0	2.4
Geologists	42.8	47.9	2.3	1.1	1.3	3.4	41.7	46.6	2.2
Physicists	20.9	24.2	3.0	1.1	1.6	7.9	19.9	22.6	2.6
Life/physical,n.e.c.	27.6	31.3	2.5	0.7	1.1	9.5	26.9	30.3	2.4
Mathematical	51.0	60.6	3.5	2.4	3.5	7.8	48.7	57.2	3.3
Social	202.3	237.0	3.2	3.0	4.0	5.9	199.3	233.1	3.2
Economists	30.3	36.2	3.6	0.8	1.3	10.2	29.5	35.0	3.5
Psychologists	90.5	106.2	3.2	1.0	1.1	1.9	89.5	105.1	3.3
Sociologists	9.3	10.7	2.8	0.1	0.1	0.0	9.2	10.6	2.9
Social, n.e.c.	72.2	83.9	3.2	1.1	1.5	6.4	71.1	82.4	3.0
TOTAL ENGINEERS	**1,142.1**	**1,423.1**	**4.5**	**139.5**	**226.4**	**10.2**	**1,002.2**	**1,196.8**	**3.6**
Aeronautical/astonautical	64.5	109.2	11.1	33.7	65.2	14.1	30.9	44.0	7.3
Chemical	53.2	60.9	2.7	2.6	3.5	6.1	50.7	57.5	2.5
Civil	163.7	188.9	2.9	3.4	4.4	5.3	160.3	184.5	2.8
Electrical/electronic	327.9	420.6	5.1	41.4	63.6	9.0	286.5	357.0	4.5
Industrial	109.5	130.8	3.6	9.7	14.9	9.0	99.8	115.9	3.0
Mechanical	202.7	248.2	4.1	19.0	29.9	9.5	183.7	218.3	3.5
Metallurgical	14.9	18.5	4.4	1.5	2.4	9.9	13.4	16.2	3.9
Mining/petroleum	27.7	31.6	2.7	0.9	1.1	4.1	26.7	30.4	2.6
Engineers, n.e.c.	178.0	214.4	3.8	27.3	41.4	8.7	150.7	173.0	2.8
TOTAL TECHNICIANS	**1,468.3**	**1,760.4**	**3.7**	**83.9**	**123.5**	**8.2**	**1,384.4**	**1,636.9**	**3.4**
Computer programmers	235.2	300.5	5.0	9.6	14.4	8.4	225.6	286.0	4.8
Drafters	312.9	368.5	3.3	1.2	23.7	6.6	295.6	344.8	3.1
Electrical/electronic engineering	345.6	421.0	4.0	28.7	42.9	8.4	317.0	378.1	3.6
Industrial	30.6	36.6	3.6	2.3	3.4	8.1	28.3	33.2	3.2
Mechanical engineering	44.9	57.3	5.0	8.4	13.6	10.1	36.5	43.7	3.7
Science/engineering, n.e.c.	499.1	576.5	2.9	17.7	25.5	7.6	481.4	551.1	2.7

NOTES: OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Because of rounding, components may not add to totals.

SOURCE: National Science Foundation

jection year as two photographs in time, without specific reference to the irregularly spaced dips and rises in demand which occur repeatedly in engineering and scientific employment.

In examining the outlook for all college graduates relative to these demand projections, BLS points out that between 1970 and 1982, employment of college graduates more than

TABLE 38

CIVILIAN EMPLOYMENT IN SELECTED S/E OCCUPATIONS WITH 5,000 WORKERS OR MORE, ACTUAL 1982 AND PROJECTED 1995

OCCUPATION	EMPLOYMENT (In thousands)				PERCENT CHANGE		
		1995			1982-1995		
	1982	Low Trend	Moderate Trend	High Trend	Low Trend	Mod. Trend	High Trend
TOTAL, ALL OCCUPATIONS	**101,510.1**	**124,846.0**	**127,109.8**	**129,902.1**	**23.0**	**25.2**	**28.0**
Professional, Technical & Related Workers	16,583.9	21,544.7	21,775.0	22,325.4	29.9	31.3	34.6
Engineers	1,204.3	1,787.0	1,788.4	1,830.6	48.4	48.5	52.0
Aero/Astronautic	43.8	65.2	61.6	62.4	48.8	40.6	42.4
Chemical	56.0	78.9	80.3	82.3	40.9	43.5	47.0
Civil	155.4	225.5	228.1	235.8	45.1	46.8	51.7
Electrical	319.5	530.5	528.2	540.3	66.0	65.3	69.1
Industrial	160.2	225.9	226.7	232.3	41.0	41.6	45.0
Mechanical	209.1	313.9	318.0	327.2	50.1	52.1	56.5
Metallurgical	14.0	20.5	20.7	21.0	46.1	47.5	50.2
Mining	5.7	6.9	7.0	7.1	21.2	22.4	24.7
Nuclear	6.3	9.4	9.3	9.7	50.5	47.9	53.9
Petroleum	26.1	31.2	31.8	30.2	19.4	21.7	15.7
Life & Physical Scientists	271.0	343.0	341.7	348.4	26.6	26.1	28.6
Agricultural	21.7	25.7	25.7	26.3	18.8	18.6	21.5
Biological	51.6	71.3	70.4	72.7	38.1	36.3	40.9
Chemists	88.8	107.0	108.3	110.9	20.5	22.0	24.9
Geologists	48.6	60.1	60.1	58.8	23.6	23.6	20.9
Medical	7.2	9.4	9.5	9.8	30.1	31.8	35.6
Physicists	18.8	26.4	25.7	26.6	40.2	36.6	41.0
Math Specialists	47.9	62.6	61.6	63.3	30.5	28.6	32.1
Actuaries	8.2	10.8	10.9	11.1	31.5	33.0	34.8
Mathematicians	10.6	14.1	13.5	14.0	33.1	28.1	32.3
Statisticians	20.1	26.1	25.8	26.6	29.5	28.3	32.0
Engineering & Science Technicians	1,243.3	1,648.6	1,660.8	1,704.6	32.6	33.6	37.1
Drafters	302.4	309.3	317.6	327.3	2.3	5.0	8.2
Electrical/Electronic	366.2	585.0	588.5	601.7	59.8	60.7	64.3
Industrial Engineering	27.4	35.9	35.4	36.6	30.9	28.9	33.4
Mechanical Engineering	47.8	72.0	72.4	74.0	50.8	51.6	54.8
Surveyors	43.6	61.3	62.4	64.3	40.5	43.1	47.3
Computer Specialists	520.8	934.8	942.8	960.0	79.5	81.0	84.3
Programmers	266.4	465.3	471.3	479.6	74.6	76.9	80.0
Systems Analysts	254.4	469.5	471.4	480.3	84.6	85.3	88.8
Social Scientists	205.6	266.8	266.7	273.2	29.8	29.7	32.9
Economists	30.0	38.7	38.0	39.1	28.9	26.6	30.4
Psychologists	82.5	109.3	109.9	112.4	32.5	33.2	36.2
College & University Teachers	744.0	619.4	632.5	646.2	-16.7	-15.0	-13.1
Graduate Assistants	139.8	121.6	124.2	126.9	-13.1	-11.2	- 9.3

Source: Bureau of Labor Statistics

doubled, and the proportion of workers with college backgrounds increased from 26% to 39% of all workers. But the proportion of college graduates employed in professional, technical and managerial occupations declined because these occupations did not expand rapidly enough to absorb the growing supply of new graduates. Consequently, one of every five graduates who entered the labor market between 1970 and 1982 took jobs not usually requiring a degree. This oversupply of graduates is likely to continue through 1995. However, the oversupply is not spread evenly across all fields.

BLS projects a 30% to 35% increase in the employment of professional, technical and related workers between 1982 and 1995, depending on economic and productivity increases. Total employment increases for all occupations during that period are only 23% to 28%, indicating that growth will be more rapid in the professional and technical areas than in many other occupational groups. However, among the groupings that include scientists and engineers, there is again a wide variation by field as shown in Table 38.

Within the sciences, percentage increases over the 13 years range from a low of 18.6% in the moderate trend figures for agricultural scientists to a high of 40.2% for physicists. Engineers show average growth of 48.5%, ranging from a 21% increase for petroleum engineers to a 65.3% increase for electrical/electronic engineers. Employment of computer specialists rises 81% in these projections, while the number of engineering and science technicians grows 33.6%.

BLS projects an actual decrease of 13% to 17% for college and university teachers over this period, although the decrease probably will not occur to the same degree across all academic fields.

These employment projections are not matched with supply projections, but if students continue to graduate proportionately in about the same fields as in the early 1980s, no significant shortages are apparent, and fields with present surplus graduates probably will continue to have some surplus.

Although the number of 18-21 year olds began to drop in the early 1980s, college enrollments continued to increase slightly as older students returned to campus in increasing numbers. By mid-decade, however, the increase had levelled off. Nonetheless, enrollments are not expected to drop off nearly as much as the drop in size of the 18-21 year group, since many schools are actively recruiting foreign students and non-traditional students. Such non-traditional student groups would appear to be less likely than those in the typical age group to choose majors in science and engineering. If this is so, the number of degrees awarded in these fields probably will continue to drop for several more years, although some fields within the S/E grouping may rise at the expense of others.

If shortages do occur in fields now expected to be in balance, there remains a substantial supply of graduates from previous years who could be encouraged to update their skills and re-enter the S/E labor force.

Continuing shortages are foreseen in some areas of specialization and in some job sectors. Present faculty shortages in engineering and computer science are unlikely to be made up by new U.S. graduates through this decade, since the number of Ph.D. awards to U.S. citizens in these fields is not sufficient to fill all needs.

On the other hand, the number of graduates anticipated in some of the science fields is significantly higher than the number of job openings expected to be available, thus indicating a larger supply than is needed for growth in employment and replacement of those in the present workforce who die, retire or otherwise leave the profession. This does not mean that there will be a large scale increase in unemployment of graduates in these fields. It may mean, however, that some graduates will be required to find employment outside their field of training.

Direct employment of all graduates in occupations closely related to their college majors is not necessarily desirable, nor does it represent optimum utilization of education either for the nation or for the individual. If the U.S. is to maintain a technological lead among the nations of the world, it must have persons involved in the decision-making processes of both government and industry who have training in science and engineering.

In contrast with a number of other developed countries, most U.S. industrial management is made up of leaders trained in the law, marketing, accounting and finance rather than in engineering or science. The managers and directors of industry in our principal technological competitors, Japan and West Germany, are predominately trained in engineering.[44] In Japan, about half of senior civil service employees hold engineering degrees (and half of these hold postgraduate degrees) permitting government planning by managers educated in technology. Senior civil servants in the U.S., as well as members of the Congress, are far more likely to be trained in law.

The economic measures of the Reagan administration have been designed to improve capital formation through modification of the tax

laws, in order to revitalize U.S. industry, introduce modern technologies, improve productivity and increase U.S. competitiveness in the world market. Whether these measures can be maintained in the face of current budget deficits is questionable. Further, any significant revitalization of U.S. industry will require not only the capital formation needed for such revitalization; it will require technologically trained manpower to design, manufacture, install and maintain new machinery and equipment, to carry out the basic research which is the basis for new innovation, and the targeted research which builds on basic research for specialized applications. If the presently perceived need for the scientists and engineers who can perform these tasks is converted to demand by the addition of capital to pay for their services and equipment, the supply of technologically trained specialists may not be sufficient to meet the demand.[45]

Whether supply and demand are or will be in balance depends at least in part on the viewpoint of the observer. When individual scientists or engineers, the professional societies for their disciplines, and employers all agree that a shortage or surplus exists, it probably does. When employers see shortages and individuals and their professional societies see surpluses, supply and demand may well be in approximate balance.

SUMMARY AND CONCLUSIONS

Some trends in scientific and engineering manpower supply and demand seem fairly certain. Except in the computer areas, the supply of most scientists appears to have caught up with, and generally exceeded the number of job opportunities in science. Nonetheless, actual unemployment continues to be low among scientists, relative to unemployment of other groups with similar amounts of education and training.

For engineers, the picure is not so clear. The number of new engineers graduating at the baccalaureate level has been rising since 1975, and the increase can be expected to continue at least through 1987. Some projections indicate that it will continue upward through 1995. A high level of demand has not only fueled that increase, but has utilized so many engineering graduates at the baccalaureate level that graduate enrollments of U.S. students have not climbed commensurately and shortages of Ph.D. engineers have become serious through the first half of this decade, at least in academic institutions. Administration programs continue to bolster defense, and industry also has opened up new employment opportunities in most engineering fields. These increases may continue through the decade, unless the nation goes into another recession. The supply of some kinds of engineers may exceed the demand, but there may be shortages in some engineering disciplines.

The level of funding that will ultimately be established by the Congress and accepted by the President for programs with high technological content, as well as the general levels of funding from both industry and govenment to support research and development will be major determinants of actual demand. These decisions will be important not only in setting the total numbers of scientists and engineers to be employed, but also in determining the relative mix of scientists and engineers that will be desired. The inability to forecast what these governmental decisions will be is a major reason why dependable forecasts of supply and demand are not readily available. Neither is it possible to predict the unexpected discovery or happening that will change the direction or scope of these efforts.

Increasing or decreasing the supply of trained scientists and engineers requires a lead time of four to eight years. Thus, changes in supply will always lag behind changes in demand. There are now and will continue to be for the foreseeable future some imbalances in supply and demand among scientists and engineers. However, when more persons are trained in these disciplines than are needed for direct employment in them, more technologically trained persons are available for other activities which will benefit from their inclusion. The universities that train scientists and engineers could assist many of their students who will move into nontraditional activities by providing or even requiring some vocational preparation beyond the narrow confines of the academic discipline. Individual students, if aware of the likelihood of employment outside the discipline and of some of the nontraditional careers that have been undertaken by graduates in the seventies and early eighties, may take it upon themselves to acquire additional education or training that would be useful in such careers.

Only if unemployment among scientists and engineers equals or exceeds the unemployment rate of all persons with similar amounts of education can we assume that supply/demand imbalances require action for reasons of large oversupply.

On the other hand, if shortages of trained manpower in any area become acute enough to curtail or delay vital programs, this will indicate a serious lack of foresight among planners, or a failure to supply known information about the job market to those individuals, universities, and employers who need the best available information in order to make informed decisions and plans.

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SCIENTIFIC, ENGINEERING, TECHNICAL MANPOWER COMMENTS, periodical, 10 issues per year, 1 yr., $35; 2 yrs., $65; 3 yrs. $95.

A monthly digest of current developments affecting the recruitment, training and utilization of scientific, engineering and technical manpower. Special sections include current information on supply and demand, salaries, women and minorities in science, education, pending legislation, federal agency activities, and new publications of interest to producers and users of technical manpower.

PROFESSIONAL WOMEN AND MINORITIES, A Manpower Data Resource Service, Fifth Edition, Aug. 1984, $70

A comprehensive reference book of manpower data presented in approximately 400 tables and charts, with breakouts by sex and/or minority status, compiled from more than 200 sources. Data on enrollments, degrees, and general, academic and federal work force participation by field and subfield are supplemented with textual highlights; annotated recruitment resources for women and minority professionals, by field; a comprehensive cross index; and an extensive bibliography.

SALARIES OF SCIENTISTS, ENGINEERS AND TECHNICIANS, A Summary of Salary Surveys, Twelfth Edition, August, 1985, $35

A 196 page report presenting detailed information on starting and advanced salaries in industry, government and educational institutions with breakouts by field, highest degreee, sex, years since first degree, age group, category of employment, work activity, type of employer, geographic area, academic rank, Civil Service grade and grade distribution, and level of responsibility, with some comparative salary data in non-technical fields.

OPPORTUNITIES IN SCIENCE AND ENGINEERING: A Chartbook Presentation, Second Edition, November, 1984, $15

This 96 page presentation includes information on the present supply of men and women scientists and engineers, detailing such characteristics as their educational preparation, their labor force participation and employment opportunities, and their starting and advanced salary levels. The future supply of and demand for scientists and engineers is examined by field under different scenarios for various periods in the future. Each page of text is accompanied by a full page chart outlining some of the statistical information included in the 20 appendix tables. The charts are suitable for reproduction.

GUIDE TO DATA ON SCIENTISTS AND ENGINEERS, April, 1984, free to libraries.

This 275 page reference book consists of three indexes to science and engineering manpower data that are published by 49 organizations concerned with some phase of science or engineering manpower. The Bibliogaphic Index describes each publishing organization, outlines the manpower surveys it conducts, and lists detail of data tables in each of its publications covering 1973-83. A Field Index and Year of Data Index are quick guides for any data characteristic, which reference back to the Bibliographic Index.

THE SCIENCE AND ENGINEERING TALENT POOL, Proceedings of the 1984 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission, May 15, 1984, $10

The 55 page report includes charts and text of several presentations about the sources for scientists, engineers and teachers over the coming decade; and opportunities for equal access for all students.

THE INTERNATIONAL FLOW OF SCIENTIFIC AND TECHNICAL TALENT: Data, Policies and Issues, Proceedings of the 1985 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission, May 7, 1985, $15

Presentations at this all-day meeting include data on the participation of foreign students and immigrant scientists and engineers. Discussions of present policies in regard to admission of foreign students for study, and requirements for change of visa status to obtain U.S. employment after graduation; plus the issues involved in U.S. utilization of foreign national scientists and engineers as seen by practicing scientists and engineers, academic departments in computer science and engineering, industry, and government, provide a lively dialogue.

ERRATUM: The correct Table 18 is printed below.

TABLE 18

EXPERIENCED SEC PERSONNEL IN THE U.S. WHO ARE FOREIGN CITIZENS BY FIELD AND PLACE OF BIRTH, 1982

	Total	U.S. Born	Foreign Born						No Response
			Total	Africa	Asia	Latin Am.	No. Amt	Other	
All S/E Fields	63,469	1,621	61,022	2,196	30,444	5,359	22,614	409	827
All Science	19,622	544	18,760	892	8,169	1,327	8,166	206	318
Physical Sciences	7,271	167	7,069	265	3,455	265	3,003	81	34
Earth, Env. & Marine Science	827	0	817	0	388	74	337	18	10
Mathematical Sciences	1,863	36	1,684	151	611	196	692	34	142
Life Sciences	3,942	43	3,833	170	1,504	363	1,786	10	67
Social Sciences	4,951	289	4,627	242	2,103	396	1,823	63	36
Psychology	768	9	728	63	108	33	524	0	30
Engineering	38,687	878	37,346	1,091	19,107	3,738	13,226	184	463
Civil	5,160	47	4,932	39	2,740	827	1,326	0	182
Elecrical/Electronic	9,103	359	8,609	398	5,466	564	2,145	36	135
Mechanical	8,413	231	8,119	219	3,498	474	3,928	0	63
Other	16,011	241	15,686	435	7,403	1,873	5,827	148	83
Computer Science	5,160	199	4,916	213	3,167	294	1,222	20	46

† Includes Europe and Soviet Union

SOURCE: Division of Science Resources Studies, NSF; Bureau of Census.